Naval Research Laboratory

Washington, DC 20375-5320

NRL/MR/7230--12-9402

Virginia Coast Reserve 2007 Remote Sensing Experiment

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March 9, 2012

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
09-03-2012

2. REPORT TYPE
Memorandum Report

3. DATES COVERED *(From - To)*
October 2007 – June 2010

4. TITLE AND SUBTITLE
Virginia Coast Reserve 2007 Remote Sensing Experiment

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
71-9824-A9

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Research Laboratory, Code 7230
4555 Overlook Avenue, SW
Washington, DC 20375-5350

8. PERFORMING ORGANIZATION REPORT NUMBER
NRL/MR/7230--12-9402

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Geospatial-Intelligence Agency
12310 Sunrise Valley Drive
Reston, VA 20191

10. SPONSOR / MONITOR'S ACRONYM(S)
NGA

11. SPONSOR / MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
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14. ABSTRACT
This report describes data collected during the first of a series of NRL remote sensing and calibration and validation (Cal/Val) campaigns undertaken to develop models of coastal environments for use in rapidly processing hyperspectral imagery (HSI) and generating shallow water bathymetric charts and trafficability maps. This report documents airborne HSI and sea and ground truth observations made at the Virginia Coast Reserve Long Term Ecological Research (VCR LTER) site during August 15–16, 2007 and Septemer 4–21, 2007. Airborne imagery was obtained from three NRL sensors, two hyperspectral and one thermal. Coordinated water and land spectral and geotechnical Cal/Val data were taken across multiple sites along the VCR barrier island chain from Smith Island to Parramore Island, as well as at several coastal mainland sites along VCR shallow bays, and at sites further north near Chincoteague Island. Cal/Val data supported the development of a first-of-a kind trafficability map derived from HSI, as well as shallow water bathymetry products, all of which were presented at a sponsor demonstration day at the conclusion of the experiment.

15. SUBJECT TERMS

Hyperspectral	Bathymetry
Trafficability	Remote sensing

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Charles Bachmann
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(include area code)*
Unclassified Unlimited	Unclassified Unlimited	Unclassified Unlimited	UU	169	(202) 767-3398

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND ACRONYMS

AAUS	American Academy of Underwater Sciences
ABCRC	Anheuser-Busch Coastal Research Center
ASOS	Automated Service Observing System
BST	Bathymetry, Salinity, Temperature
Cal/Val	Calibration/Validation
CASI	Compact Airborne Spectral Imager
CNMI	Commonwealth of the Northern Mariana Islands
DCP	Dynamic Cone Penetrometer
DoD	Department of Defense
DPRI	Defense Policy Review Initiative
EAARL	Experimental Advanced Airborne Research Lidar
GCP	Ground Control Point
GIS	Geographic Information Systems
GPS	Global Positioning System
GSD	Ground Sample Distance
HALE	Hydrodynamic Agents in the Littoral Environment remote sensing campaign
HI-HARES'09	Hawaii-Hyperspectral Airborne Remote Environmental Sensing experiment of 2009
HSI	Hyperspectral Imagery
InGaAs	Indium gallium arsenide
InSb	Indium antimonide
km	kilometer
LIDAR	Light Detection and Ranging
LTER	Long Term Ecological Research
LWD	Light Weight Deflectometer
MARFORPAC	United States Marine Corps Forces Pacific
MCOTEA	Marine Corps Operational Test and Evaluation Activity
mm	millimeters
ms	milliseconds
MWIR	mid-wavelength infrared
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NGA	National Geospatial and Intelligence Agency
nm	nanometers
NOAA	National Oceanic and Atmospheric Administration
NRL	Naval Research Laboratory
NSWC	Naval Surface Warfare Center
PAR	Photosynthetically Active Radiation
SAV	Submerged Aquatic Vegetation
SWIR	short-wavelength infrared
TS'09	Talisman-Saber Remote Sensing Campaign of 2009
USMC	Untied States Marine Corps

VCR’07	Virginia Coast Reserve Remote Sensing Campaign of 2007
VNIR	visible and near-infrared

EXECUTIVE SUMMARY

A remote sensing campaign and *in situ* validation by the Naval Research Laboratory (NRL) was conducted during September 2007 at the Virginia Coast Reserve (VCR), which is a National Science Foundation funded Long Term Ecological Research site on the Eastern Shore of Virginia. The study area comprised a 1,880 km^2 region consisting of islands, inlets, shallow water lagoons, and mainland marsh systems. Environmental factors within this location make up a barrier island coast that is associated with high spatial and temporal variability. Owing to rapid changes in coastal features and sparse data holdings in these kinds of littoral regions, recent imagery of the coast is necessary to provide spatially extensive information that includes environmental factors which impact the maintenance of naval training areas, the conduct of training, and the planning and execution of naval expeditionary force operations.

NRL's remote sensing research goals focused on characterizing shallow water bathymetry, coastal vegetation, and trafficability since these important variables support decision makers managing training beaches (e.g., Onslow Beach at Camp Lejeune), personnel concerned with safety and fielding of new equipment (e.g., the Expeditionary Fighting Vehicle), and campaign planners concerned with maneuver in a complex and dynamic coastal zone (e.g., Seabasing and Joint Logistics Over the Shore). The barrier island coast at the VCR was an ideal study location because:

- This site provides a rich archive of data to validate the use of overhead imagery to characterize coastal inlets, surf zones, beaches, maritime forests, wetlands, tidal flats, and coastal lagoons;
- Natural lands and built up areas along Cape Charles, VA are representative of barrier island coasts, worldwide; and
- It is a major natural resource for the Mid Atlantic Region.

Imagery-derived information for barrier island coasts can be used to support military planning, especially to site a littoral penetration point, determine how one might breach the surf zone, and find exits off the beach. In response to integrated and prioritized requirements, especially in providing environmental information in complex coastal regions, NRL has developed procedures for terrain characterization, to extract bathymetry, and to build trafficability maps in barrier coast environments. These products would be especially useful in helping to phase the offload of material from amphibious shipping to the shore. This data report provides documentation on observations and information for decision-making on barrier islands. It is the foundation for other scientific literature, future remote sensing campaigns, and the development of geodatabases for other coast types.

Observations in the coastal zone offer a variety of challenges associated with land, ocean, and atmospheric boundaries and their respective interfaces. These challenges may limit the possibilities for collecting both *in situ* and remote data. The coastal zone is especially dynamic because physical and biological observations reflect (1) land, air, and sea interactions, (2) the mixed spectral signatures of coastal and hinterland vegetation, and (3) the especially complex structures generated by biological activity. There are also temporal fluctuations in coastal types, which may require long time-series observations with enough frequency to determine features such as the amount of available beach at all phases of the tide along a barrier island coast. While barrier island remote sensing promises to address some of these difficulties, there are challenge

to integrating remote and *in situ* observations for other coast types such as mangrove and coral reef coast monitoring.

Amphibious planners and environmental managers need improved mapping of coasts. This will require the development of similar or hierarchical classification systems for environmental factors, research into their functional interpretation, higher resolution imagery to resolve coastal features, hyperspectral imagery able to distinguish between environmental factors, and new approaches to integrate remote sensing information at various scales. For coastal classification, long-term monitoring programs are required at multiple sites, using imagery with sufficient spatial and spectral resolution to identify changes in the environmental factors, correlating observed changes (e.g., from imagery time series) with oceanographic, terrestrial, atmospheric and climatic trends (e.g., from the International Comprehensive Ocean Atmospheric Dataset), and linking present information (*in situ* sensors and current imagery) with the reconstruction of past trends (encyclopedic information).

For remote sensing observations of barrier island coasts, there were two goals:

1. Obtain high spatial resolution (1-5 m) hyperspectral imagery for mapping and monitoring landing beaches to provide very shallow water bathymetric soundings and bearing strength maps.
2. Collect information on beach sediments (shear and bearing strength), vegetation (type and density), atmospheric properties (atmospheric temperature, humidity profiles, optical depth, wind speed and direction), and oceanographic properties (sea surface temperature, salinity, bottom reflectance, depth, currents, water level, and turbidity).

Reaching these goals allowed NRL to merge *in situ* data with imagery to develop and demonstrate imagery-derived shallow water bathymetric charts and trafficability maps shortly after airborne surveys.

For the VCR campaign, NRL mounted sensors in a de Havilland Twin Otter airplane. The remote sensors included a Compact Airborne Spectral Imager (CASI), which is a visible near infra-red (VNIR) hyperspectral camera operating in the 0.38-1.04 micron spectral range, a Surface Optics short-wave infra-red (SWIR) camera operating in the 0.9-1.7 micron range, and a single channel mid-wave infra-red (MWIR) camera operating in the 3-5 micron range. Additional data were also obtained during the last few days of the exercise during coincident flights by the NASA EAARL LIDAR.

This data report focuses primarily on the information that was collected to support the development of shallow water bathymetry and trafficability maps. The calibration and validation of these imagery results involved *in situ* spectral and geotechnical measurements of substrates taken from 100 sites across transects on four of the barrier islands (Wreck Island, Hog Island, Parramore Island, and Smith Island, VA). The *in situ* validation campaign covered the period from 4 through 21 September 2007, while airborne remote sensing coverage by the NRL VNIR, SWIR, and MWIR cameras took place during the period from 7 through 21 September 2007. The *in situ* spectral and geotechnical measurements were used to characterize the bearing strength of the substrate, its moisture content and grain profile size, as well as its corresponding spectral

reflectance. These measurements were used to develop a spectral look-up table for bearing strength, and the look-up table was later used to develop maps of the substrate bearing strength directly from CASI hyperspectral remote sensing imagery. *In situ* measurements for characterizing the substrate during the campaign consisted of spectral reflectance measurements made using two Analytical Spectral Devices full range spectrometers, a Zorn Light Weight Deflectometer (LWD) for measuring the bearing strength, a Dynamic Cone Penetrometer (DCP) for measuring shear strength, and a soil grab sampler to obtain samples for use in soil moisture and grain profile analysis. All data and imagery were archived in a project geodatabase. NRL's remote sensing campaign at the VCR identifies a logical method to improve the processing of imagery and production of coastal maps in a barrier island coast.

Operational organizations should be provided with the capability to enhance coast type geodatabases with higher resolution airborne or satellite measurements. The geodatabase can then be used to build amphibious products that support maneuver planning (shallow water bathymetric charts, vegetation layers, trafficability maps, etc.). NRL's method of rapidly building geodatabases and exploiting hyperspectral imagery should be transitioned to military planners that are concerned with specific coast types. To improve training area management and safety, information products from imagery-derived sources must be generated and linked to processes of importance to that particular coast type. For example, wave impacts on a barrier island coast are different from those found on a coral coast and the specific factors associated with a particular coast should be identified to support those involved with geospatial information, e.g., the imagery and mapping communities.

Introduction

The Virginia Coast Reserve 2007 (VCR '07) experiment was built upon seven years of prior research (Bachmann et al., 2002, 2003; Bachmann, 2003), as well as other related projects that focus on algorithm development for hyperspectral imagery (HSI) exploitation (Bachmann, Ainsworth, Fusina, 2005, 2006). Bachmann et al. (2007) provide an example of research at the VCR that was centered on precision mapping of coastal land-cover as well as vegetation density (biomass). Trafficability and shallow water bathymetry products developed during VCR'07 are summarized in two journal publications (Bachmann, Nichols, et al, in press; Bachmann, Montes, et al, 2010). Bachmann's research thrust is now oriented on extraction of shallow water features and trafficability parameters from spectral region imagery (Bachmann, Fusina, Nichols, McDermid, 2008). He is developing software that uses distinct features observed in specific coast types that support the development of imagery-based products that can be used for mobility planning (Bachmann, Fry, Fusina, Nichols, 2010). Imagery derived products could be used as inputs to the NATO Reference Mobility Model II or to support Joint Logistics Over the Shore. This experiment uses the VCR to study a barrier island coast with coastal lagoons, tidal inlets, and extensive mud flats; scientific effort during VCR'07 helps to characterize this type of coast.

This data report presents airborne HSI and sea and ground truth observations that were made at the VCR during the timeframes from 15 to 16 August 2007 and 4 through 21 September 2007. The goals for this remote sensing campaign were to collect site data and extract very shallow water depths and develop trafficability products from overhead imagery, especially HSI imagery. The VCR'07 effort was partially supported by NGA, which supplied funding for a trafficability experiment, shallow water and inter-tidal analyses, and a new product demonstration involving a multi-sensor airborne data collection and simultaneous *in situ* calibration and validation effort (Bachmann, Nichols et al, 2008; Bachmann, Montes, et al, 2008; Bachmann, Nichols et al, in press; Bachmann, Montes et al, 2010). The primary experiment included collaborators from industry, several universities, and NRL, all working at the VCR, an 1,880 km^2 region of barrier islands, shallow water lagoons, coastal inlets, and tidal creeks on Virginia's Eastern Shore. A significant result is the barrier island geodatabase, which characterizes important features used to extract bathymetry and to estimate bearing strength.

The VCR'07 experiment was conducted at one of the National Science Foundation's (NSF) Long Term Ecological Research (LTER) study areas (LTER, 2007). The VCR has significant infra-structure and historical environmental data that supported this remote sensing campaign and innovations such as the development of an imagery-derived trafficability map. Trafficability is the capability of terrain to bear traffic. Mobility studies need trafficability information and have real value in a variety of fields from military planning (USMC, 2000) to civil engineering (Holtz and Kovacs, 1981). The VCR'07 campaign culminated in an on-site demonstration day held at the University of Virginia VCR/LTER field station, also known as the Anheuser Busch Coastal Research Center (ABCRC). Attendees included the project sponsor, Dr. Chung Hye Read and Admiral Chris Andreasen of NGA and representatives from Marine Corps Operational Test and Evaluation Activity (MCOTEA), Marine Corps Forces Pacific, Naval Surface Warfare Center (NSWC) Carderock Division, and the Office of Naval Research. Several of these DoD organizations are potential transition partners for algorithms that will be developed though continued research and development. The MARFORPAC science advisor was especially interested in this work owing to information gaps for planning amphibious operations and

Manuscript approved September 22, 2010.

elements of the Defense Policy Review Initiative (DPRI), which relates to developing new training areas in the Commonwealth of the Northern Mariana Islands (CNMI). Representatives from NSWC Carderock and MCOTEA were interested in environmental characterization to support development of the Joint Maritime Assault Connector, Expeditionary Fighting Vehicle, and Transition Craft.

Data collected from the VCR were archived in an ArcGIS geodatabase containing attribute information, shapefiles of the research area, as well as trafficability, and bathymetry products. Attribute data describes spatial features but is not inherently graphic. For example, an attribute associated with a beach might be its name or the height of tide when it was imaged. Shapefiles are basically a data structure describing points, lines and polygons. The VCR'07 geodatabase is part of a growing set of coastal environmental geodatabases being developed at NRL. The geodatabases are standardized to allow the comparison of specific data elements, parameters, and phenomena important for processing and exploiting spectral region imagery. Other preliminary geodatabases maintained by NRL include the Han River Estuary, Pearl River, Kaneohe Bay, and Shoalwater Bay. Early presentation of research at the VCR for the mapping and remote sensing community also interested naval architects from NSWC Carderock in development of an annotated bibliography on environmental research supporting amphibious craft development as well as an environmental support plan (Bachmann, Fusina, Nichols, et al., 2008 and Nichols 2007). Following VCR'07, the science advisor from MARFORPAC established an NRL hyperspectral exploitation group to participate in Exercise Talisman Saber 2009. The science advisor also helped plan a remote sensing campaign for Guam and Tinian Islands, which are part of the CNMI. Geodatabase use facilitates comparison and contrasting coast types and is described in Bachmann, Fry, et al., 2010.

Dr. Charles Bachmann (Code 7232), the NRL principal investigator for VCR'07, has also proposed related work for a new applied research program (a several year 6.2 base program) which will begin in FY11, a Coalition Warfare Program with the Australia Defence Force's Defence Science and Technology Office, and to secure the transition of this capability, a Joint Concept Technology Demonstration. Components of the 6.2 new start program include the transition of algorithms for trafficability from multi-sensor imagery. In each proposal, a major component of transition includes adding appropriate spectral libraries and algorithms into the Topographic Production Capability to enable topographic Marines to build their own trafficability maps for representative coast types.

1 Field Experiment

The study area is located at the southern tip of the Delmarva Peninsula and encompasses the southern portion of the VCR. The geography includes mainland watersheds, tidal marshes, lagoons, and barrier islands along a 110km segment at the southern tip of the Delmarva Peninsula (Figure 2.1). The mouth of the Chesapeake Bay and Virginia Beach are located to the South. It is an optimal location for research in a barrier island system, where natural obstacles include shifting channels and shoals. Laboratory work was accomplished at the ABCRC located in Oyster VA, which is depicted in Figure 1.2. Considerable data were collected and analyzed in the field. Table 1.1 depicts primary types of data that were collected and archived. Other electronic resources are listed in Appendix A.

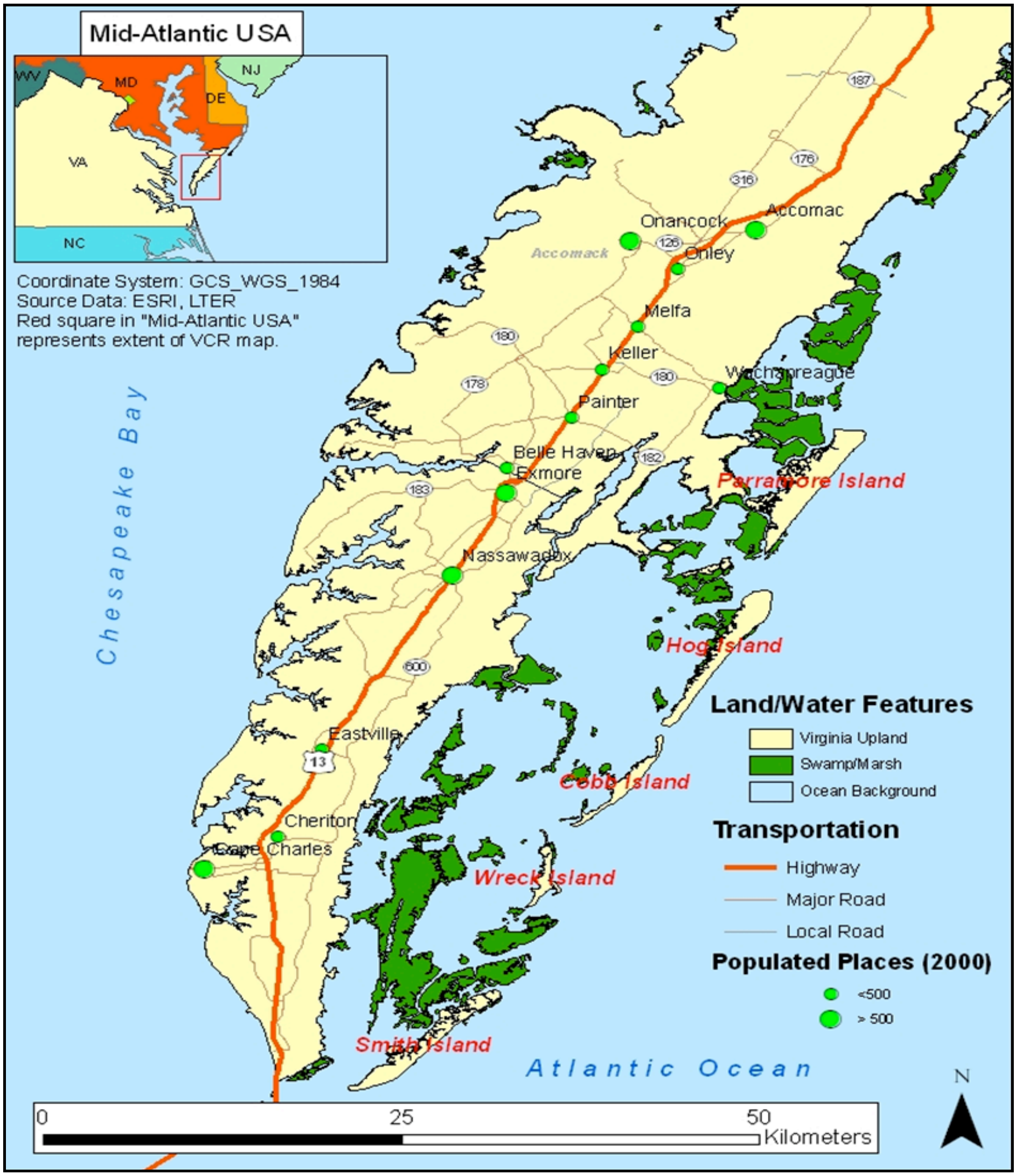

Figure 1.1. Geography of southern VCR. This barrier island location is one of 26 sites that comprise the NSF's LTER Network. The Network includes a wide range of coasts from Alaska to Antarctica and from the Caribbean to French Polynesia.

Figure 1.2. Location of ABCRC in Oyster, VA. This field station provides laboratory and dormitory facilities, logistics and technical support to visiting researchers. Quality controlled ABCRC observations include data from meteorological stations, tide gauges, and water level recorders. (Insert) ABCRC and dock area used during VCR'07.

The VCR remote sensing campaign included (1) a site reconnaissance with coincident data collection at Indiantown on 15 August 2007 and at Boxwood, Cushman's Landing, and Gator Creek on 16 August 2007, (2) sea and ground surveys on several of the VCR barrier islands from 4 through 21 September 2007, and (3) aerial surveys from 7 through 21 September 2007. The *in situ* spectral and geotechnical measurements were taken to understand relationships between the bearing strength of the substrate and its corresponding surface spectral reflectance. These measurements were used to develop a spectral look-up table for bearing strength, and the look-up table was later used to develop maps of the substrate bearing strength directly from the CASI hyperspectral remote sensing imagery. The purpose of combining *in situ* measurements was to develop models for bearing strength retrieval from substrates (i.e., trafficability analysis), recognizing that the most significant factors would be related to composition, grain size, and substrate moisture, and in particular to relate these to the observed spectral reflectance. Air operations were conducted out of the Ocean City Municipal Airport (OXB) and raw imagery was driven to the ABCRC for processing. Table 1.1 displays the location and date of collection of attribute data during the VCR'07 campaign. A demonstration of instruments and procedures, tour of Wreck Island (one of the barrier island cal/val sites) and resultant products were presented on 20 September, 2007 at the ABCRC.

Table 1.1. Attribute Data Collection Locations. Most data were processed in the field at the ABCRC. Abbreviations indicate the location or type of data that were collected. The data collected are listed in rows in the first column and each day is annotated at the top of the column. The bottom portion of the table lists the abbreviations used in the upper portion of the table.

Data		15-Aug	16-Aug	05-Sep	06-Sep	07-Sep	08-Sep	09-Sep	10-Sep	12-Sep	13-Sep	16-Sep	17-Sep	18-Sep	20-Sep
ASD(Spectra)	Site	IT	B, CL, GC	S	P	H	S	N/A	W	P	W	P	N/A	IT, U	N/A
	Local Feature/Leaf (In Situ)	N/A	N/A	N/A	N/A	H	S	N/A	S	N/A	W(SAV)	N/A	N/A	N/A	N/A
	Shallow water Bathymetry	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	P	W	N/A	N/A	N/A	N/A
Biomass		N/A	N/A	S	P	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ceptometer		IT	CL	S	P	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DCP		IT	N/A	S	P	H	S	N/A	W	P	W	P	N/A	N/A	N/A
Dive Spec		N/A	N/A	N/A	N/A	N/A	N/A	N/A	S	P	N/A	N/A	N/A	N/A	N/A
GPS	Sites	IT	N/A	S	P	H	S	N/A	W	P	W	P	N/A	N/A	N/A
	BST	N/A	N/A	N/A	N/A	N/A	N/A	N/A	S	N/A	N/A	N/A	W	N/A	N/A
	Ground Control Points	CL(Dock)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	P(Bridge)	N/A	N/A	N/A
Hyperspectral Imagery- CASI		N/A	N/A	N/A	N/A	C,H	C,S,W	N/A	H, P	H, P	C,CT,H,S,W	H, P	C, P	N/A	N/A
LWD		IT	CL	S	P	H	S	N/A	W	P	W	P	N/A	N/A	N/A
Photographs		IT, CL, SL	CL	S	P	H	S	L	S, W	P	W	L, P	W	IT, L, U	L
Soil		N/A	N/A	S	P	H	S	N/A	W	P	W	P	N/A	N/A	N/A

VCR 2007 Attribute Data Abbreviations

Abbrevation	Location
B	Boxwood
BST	Bathymetry, Salinity, Temperature
C	Cobb's Island
CL	Cushman's Landing
CT	Chincoteague
GC	Gator Creek
H	Hog
IT	Indiantown
L	Anheuser-Busch Coastal Research Laboratory
P	Parramore
S	Smith
SL	Steelman's Landing
U	Upper Phillip's Creek
W	Wreck

1.1 Airborne Survey

For the VCR'07 campaign, NRL mounted three remote sensing instruments (Figure 1.3) in a De Havilland Canada DHC-6-200 Twin Otter: a CASI-1500 (ITRES, 2007), which is a visible near infra-red (VNIR) hyperspectral camera operating in the 0.38-1.04 micron spectral range, a Surface Optics short-wave infra-red (SWIR) hyperspectral camera operating in the 0.9-1.7 micron range, and a single channel mid-wave infra-red (MWIR) camera operating in the 3-5 micron range. Airborne remote sensing coverage of the VCR study area by the three cameras occurred during the period from September 7-21, 2007, while the ground campaign started three days before this on September 4 and ran through September 21. Air operations were conducted out of the Ocean City Municipal Airport which includes an Automated Surface Observing System (ASOS). NOAA ASOSs provide continuous monitoring of atmospheric conditions (i.e. temperature, precipitation type, wind speed/direction, visibility, sky conditions), in near-real time that are important to both aviation and weather forecasting. This information was used in planning daily flights as well as supporting field spectroscopy. Airborne hyperspectral imagery

can be collected during cloudy days by flying below the clouds. This works well with consistent overcast conditions since ambient lighting on all frames is similar; however, it does tend to lower overall sensor counts resulting in lower SNR. Cloud shadows can be problematic. Airborne sensor specifications are listed in Table 1.2.

Figure 1.3. VCR'07 platforms and sensors. The left panel is the Twin Otter aircraft used to support remote sensing over Cape Charles, VA. The right panel is the NRL CASI-1500 VNIR hyperspectral sensor, Surface Optics SOC-700-SW SWIR hyperspectral sensor, and single channel mid-wave infra-red camera onboard the twin otter. ONR provided platform support and data was collected simultaneously from all three sensors throughout VCR'07.

Table 1.2. Sensor specifications. These passive sensors detect natural radiation that is emitted or reflected by vegetation, morphological features, and objects found on the barrier island coasts.

Sensor	Module	Spectral Range	Number of Bands	Spectral Resolution
CASI 1500	VNIR	0.38 – 1.05 µm	up to 288	<3.5 nm (FWHM)
SOC-700-SW (InGaAs)	SWIR	0.9 – 1.7 µm	128	6.25 nm
Merlin M (InSb)	MWIR	3 – 5 µm		
Additional details on the CASI sensor may be accessed online at URL: http://www.itres.com/CASI_1500.com				
Additional details on the Surface Optics MWIR sensor can be accessed at URL: http://www.surfaceoptics.com/Products/Hyperspectral.htm				
Additional details on the Indigo Systems Merlin M camera can be accessed at URL: http://www.corebyindigo.com/PDF/SPIE/3698-97.pdf				

A composite quicklook mosaic of the CASI scenes obtained during the course of the campaign is shown in Figure 1.4. CASI is a pushbroom sensor with 288 programmable channels. The NRL airborne data collection and *in situ* validation teams were both involved in the post-processing of the remote sensing data. CASI-1500 imagery was the primary focus for

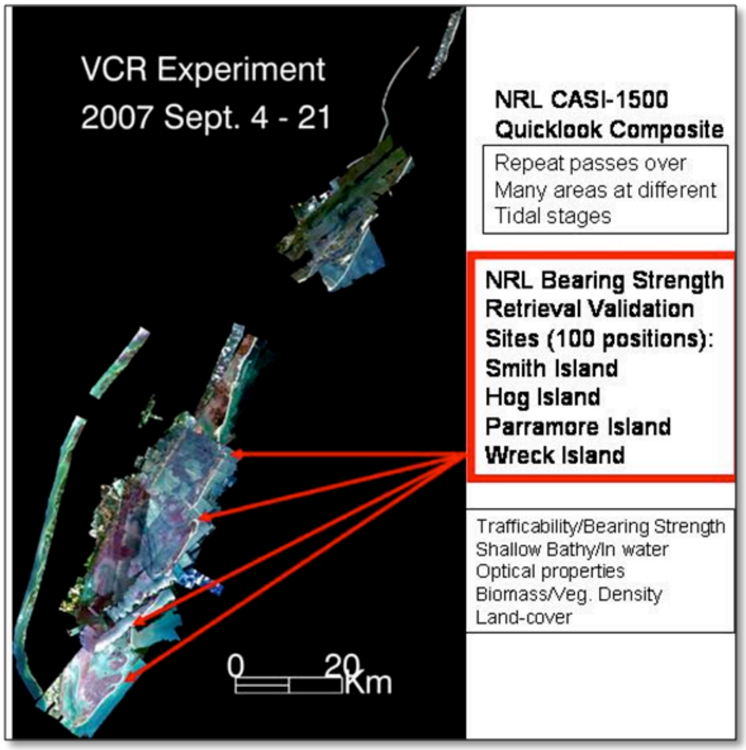

Figure 1.4. Quicklook mosaic of NRL CASI-1500 flights acquired. Many sites were surveyed at different tidal stages. Sites highlighted by red arrows indicate the locations on Smith Island, Wreck Island, Hog Island, and Parramore Island where trafficability data (spectral and geotechnical data) were gathered at 100 different locations during the course of the exercise. These data became the basis of the spectral libraries used to produce trafficability maps presented on September 20, 2007 during the sponsor's "Demonstration Day."

demonstration day on September 20, so the majority of airborne data post-processing concerned the CASI imagery during the campaign. Post-processing steps included data calibration, atmospheric correction, and georectification, as well as remote sensing product development. The raw hyperspectral images were delivered in radiance units. These images contain absorption features caused by atmospheric constituents, thus altering the spectral signature of surface features. Therefore, meteorological measurements were used in post processing to account for the influence of the atmospheric constituents (atmospheric correction). Mosaics were also printed with an HP Wide Large Format Inkjet Plotter located at the Nature Conservancy's Nassawadox field office. The Nature Conservancy owns approximately 14 of Virginia's barrier islands (The Nature Conservancy, 2007).

Considerable effort was also taken to ensure that airborne data collection and field validation efforts were coordinated. The principal investigator used cellular phones and radio to conduct planning meetings and to maintain contact with all field teams and the aircraft throughout the exercise. In addition, flight lines were planned to minimize the effects of glint over the water and marsh systems. In order to achieve this, the NRL team computed optimal times of day for data acquisition, and planned flight lines to maintain flight line trajectories into and out of the sun (USNO, 2007) . This has the benefit of minimizing glint and of maintaining uniform illumination across the sensor array. In order to maintain a heading into and out of the sun, flight line azimuthal bearing was defined for each hour in the air because the solar azimuth changes rapidly at this time of year at this latitude. Planned flight lines for VCR'07 are provided

in Appendix B. At the beginning of the September exercise, and at the VCR latitude (37°27'N), the optimal times for HSI collection are typically in 2-2.5 hour windows in the morning and afternoon, while by the end of the exercise, optimal data collection times occurred in a much broader single window extending from 9:30 AM to 4:30 PM. A typical planned set of flight lines and the corresponding CASI-1500 "quicklooks" from one of the morning data collections appears in Figure 1.5, showing the changing bearing of the data collection as a function of hour of the day. Quicklook images for each of the day's flight lines can be viewed in Appendix C.

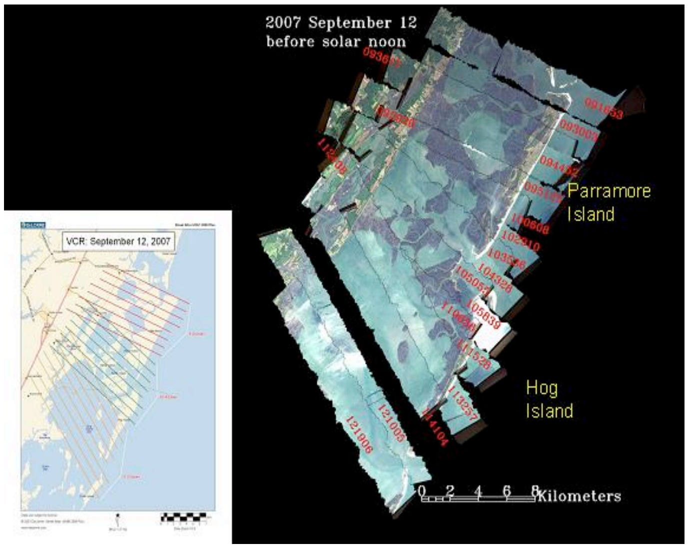

Figure 1.5. Flight line planning and example CASI flightlines. Bearings were chosen to maintain a heading into and out of the sun during data acquisition to minimize glint and maintain a uniform illumination on the sensor array.

As previously indicated, the NRL CASI-1500 is a VNIR instrument covering the 0.38-1.05 micron range, with 288 programmable spectral channels. The programmable nature of the instrument allows tradeoffs between signal to noise ratio and spectral resolution. During this experiment, the majority of the data was acquired with 92 spectral channels to produce a higher signal-to-noise ratio. The typical altitude for most flights was 3000m, and the corresponding ground sample distance (GSD) (spatial resolution) was 1.5m. At this altitude, the 1500 cross-track pixels of the CASI-1500 hyperspectral camera achieved a swath width of 2.25km. At this altitude, the spatial resolution of the Surface Optics SWIR hyperspectral camera was about 2.3m with a swath width of about 1.5km. The thermal camera was more limited, with a GSD of typically 3-4m and a swath width of about 0.75km.

For the majority of the data collections, the sensors were flown into and out of the sun to ensure uniform illumination across the sensor array. In order to ensure this, the heading of the aircraft was changed to align the aircraft with the solar azimuth angle at the center of each hour interval. Times of day were chosen to minimize glint (solar zenith angle between 35-55 degrees in most instances) from the ocean, inland water bodies, and wetland environments. Times for planning and all self-recording instruments were set to Eastern Standard Daylight Savings time.

Water level information was obtained from NOAA's tide gauges and from local ABCRC water level gauges. NOAA tide predictions were also used in planning flights and are helpful to

synchronize imagery. More information regarding water level data can be viewed in Appendix D.

1.2 Calibration/Validation Data

The *in situ* validation campaign was undertaken in conjunction with the airborne remote sensing effort described in Section 2.1. The NRL-led team undertook a series of *in situ* spectral (Appendix E) and geotechnical measurements (Appendices F, G, H) to look for relationships between the bearing strength of the substrate and its corresponding surficial spectral reflectance. These measurements were used to develop a spectral look-up table for bearing strength, and the look-up table was later used to develop maps of the substrate bearing strength directly from the CASI HSI. The resultant grain size distributions, vegetation layers, shallow water bathymetry, and trafficability maps were presented at the September 20, 2007 Demonstration Day held at the ABCRC in Oyster, VA. Analogous military products prepared by intelligence personnel would be special maps for trafficability, engineer reconnaissance, and assault maps. Such products would be in the form of an overlay.

In situ measurement data for characterizing soil substrates included:

a. spectral reflectance measurements made using two Analytical Spectral Devices (ASD) full range (FR) spectrometers (ASD, 2007),
b. Zorn ZFG2000 Light Drop Weight Tester, a type of Light Weight Deflectometer (LWD) (Hoffman, Guzina, Drescher ,2003),
c. a Kessler Dynamic Cone Penetrometer (DCP) (Kessler, 2007),
d. a soil grab sampler (for soil moisture and grain profile analysis done later in the lab) and,
e. the position of the soil site collected from a Trimble® ProXH GPS unit and the site's relative position taken in photograph documentation.

A typical work progression for *in situ* geotechnical and spectral measurement data is illustrated in Figure 1.6. Geotechnical measurement involves destructive sampling so spectroscopy is always done first. Core samples were brought to ABCRC and analyzed for grain size distribution and moisture content. The spectral and geotechnical instrument suite was used to capture 100 different positions in transects that covered four of the barrier islands in theVCR'07 remote sensing campaign.

Figure 1.6. ***In situ*** **data collection progression for VCR'07.** The top panel shows a transect with orange marker flags. (A) Spectral data collection. (B) Site marking by alphanumeric indicator. (C) LWD data collection. (D) DCP data collection. (E) Core sample collection. (F) GPS marking of site and site photography.

1.3 Site Characterization

The experiment site is the location of one of the NSF's LTER study areas, and has significant infra-structure and historical environmental data to support coastal research projects such as this trafficability study. Much of the historical environmental data can be accessed via LTER's data catalog (UVA (a), 2007). Other web resources are listed in Appendix A.

Meteorological, bathymetric, and water level data are very important as these data resources are used for calibration and validation. Meteorological data in the VCR were collected on Hog Island (Machipongo Station), Oyster, and Phillip's Creek, VA. These data are provided in tabular and graphical format. Hog Island data can be accessed in realtime (UVA (b), 2007) and is

provided over the timeframe of the study period in Appendix I. Meterological data and water level data can be obtained from the NOAA-run tidal station at Wachapreague, VA. This tide station's data can be viewed by accessing NOAA's tide and currents website (NOAA, 2007). Tide information for the study period is displayed in Appendix D. Table 1.3 describes various NOAA nautical charts covering the VCR.

Table 1.3. NOAA nautical charts. Shoreline retreat along places such as Wreck Island was not depicted on existing charts. Erosion and accretion, especially at the inlets was observed during the study.

Chart	Scale	Edition	Date	Title
12210	1:80 000	38	2008	Chincoteague Inlet to Great Machipongo Inlet; Chincoteague Inlet
12221	1:80 000	80	2009	Chesapeake Bay Entrance
12222	1:40 000	52	2009	Chesapeake Bay Cape Charles to Norfolk Harbor
12224	1:40 000	24	2006	Chesapeake Bay Cape Charles to Wolf Trap
13003	1,200,000	49	2007	Cape Sable to Cape Hatteras
Digital versions of the charts can be accessed via the URL: http://www.charts.noaa.gov/OnLineViewer/AtlanticCoastViewerTable.shtml				

High resolution hyperspectral sensors can be used to detect a spectral response from coastal plants and submerged aquatic vegetation (SAV). With proper ground truth, it is possible to determine the depth and even concentration of SAVs. For example, if the water clarity and depth has been measured at the time of imaging, the chlorophyll response can be measured. A list of all plant species contained in the VCR is displayed in Table 1.4, which includes SAV species in bold type. Submerged aquatic vegetation species studied in the VCR include *Ruppia maritima* (Widgeon grass) and *Zostera marina* (eelgrass). Submerged aquatic vegetation are important indicators of water quality, provide habitat and food resources for numerous animal species, and filter pollutants from contaminated water (VIMS, 2007). In some cases, depth estimation can be inferred from SAVs (Han and Rundquist, 2003; Wang, Traber, Milstead, Stevens, 2004; Pinnel, Heege, Zimmermann, 2004).

Table 1.4. Vegetative species inhabiting VCR. Names in bold type are SAVs.

Genus	Species	Genus	Species	Genus	Species
Acer	*rubrum*	*Centaurium*	*pulchellum*	*Geranium*	*carolinianum*
Achillea	*millefolium*	*Centrosema*	*virginianum*	*Gnaphalium*	*chilense*
Agalinis	*maritima*	*Cerastium*	*glomeratum*	*Gnaphalium*	*obtusifolium*
Agalinis	*purpurea*	*Chenopodium*	*album*	*Gnaphalium*	*purpureum*
Aira	*elegans*	*Chenopodium*	*ambrosiode*	*Helianthemum*	*canadense*
Allium	*canadense*	*Crataegus*	*viridis*	*Hibiscus*	*moscheutos*
Ambrosia	*artemisiifoli*	*Cynodon*	*dactylon*	*Hieracium*	*gronovii*
Amelanchier	*obovalis*	*Cyperus*	*esculentus*	*Hydrocotyle*	*verticillata*
Ammophila	*breviligulat*	*Cyperus*	*grayi*	*Hypericum*	*gentianoides*
Andropogon	*scoparius*	*Cyperus*	*odoratus*	*Hypericum*	*hypericoides*
Andropogon	*virginicus*	*Danthonia*	*compressa*	*Ilex*	*opaca*
Andropogon	*virginicus*	*Diodea*	*virginiana*	*Ilex*	*Vomitoria*
Apocynum	*cannabinum*	*Diospyros*	*virginiana*	*Iva*	*Frutescens*
Aralia	*spinosa*	*Distichlis*	*spicata*	*Juncus*	*Acuminatus*
Aristida	*tuberculosa*	*Eleocharis*	*acicularis*	*Juncus*	*Biflorus*
Asplenium	*platyneuron*	*Eleocharis*	*erythropoda*	*Juncus*	*Bufonius*
Aster	*tenuifolius*	*Eleocharis*	*palustris*	*Juncus*	*Coriaceus*
Atriplex	*arenaria*	*Eleocharis*	*parvula*	*Juncus*	*Debilis*
Atriplex	*patula*	*Eleocharis*	*tenuis*	*Juncus*	*Dichotomus*
Baccharis	*halmifolia*	*Elephantopus*	*sp. ?*	*Juncus*	*Gerardi*
Bacopa	*monnieri*	*Elymus*	*virginicus*	*Juncus*	*Roemerianus*
Bassia	*hirsuta*	*Eragrostis*	*cilianensis*	*Juncus*	*Scirpoides*
Berchemia	*scandens*	*Erigeron*	*annuus*	*Juncus*	*Tenuis*
Boehemeria	*cylindrica*	*Erigeron*	*canadensis*	*Juniperus*	*Virginiana*
Borrichia	*frutescens*	*Euonymus*	*japonica*	*Kosteletskya*	*Virginica*
Bulbostylis	*capillaris*	*Eupatorium*	*capillifolium*	*Krigia*	*Virginica*
Cakile	*edentula*	*Eupatorium*	*hyssopifolium*	*Lepidium*	*Virginicum*
Callicarpa	*americana*	*Eupatorium*	*pilosium*	*Limonium*	*Nashii*
Calystegia	*sepium*	*Eupatorium*	*rotundifolium*	*Linaria*	*Canadensis*
Campsis	*radicans*	*Euphorbia*	*polygonifoli*	*Linum*	*Virginianum*
Carduus	*spinosissimus*	*Festuca*	*rubra*	*Lippia*	*Lanceolata*
Carex	*festucacea*	*Festuca*	*sciurea*	*Liquidambar*	*Styraciflu*
Carex	*pensylvanica*	*Ficus*	*carica*	*Lonicera*	*Sempervirens*
Carex	*vulpinoidea*	*Fimbristylis*	*spadicea*	*Maclura*	*Pomifera*
Cassia	*fasciculata*	*Galium*	*hispidulum*	*Mikania*	*Scandens*
Celtis	*laevigata*	*Galium*	*pilosum*	*Mitchella*	*Repens*
Cenchrus	*tribuloides*	*Galium*	*tinctorium*	*Mollugo*	*Verticillata*

Genus	Species	Genus	Species	Genus	Species
Monarda	*punctata*	*Pteridium*	*aquilinum*	*Solanum*	*Carolinense*
Muhlenbergia	*capillari*	*Ptilimnium*	*capillaceum*	*Solidago*	*Microcephala*
Myosotis	*verna*	*Puccinellia*	*fasciculat*	*Solidago*	*Sempervirens*
Myrica	*cerifera*	*Quercus*	*falcata*	*Sonchus*	*Asper*
Myrica	*pennsylvanica*	*Quercus*	*laurifolia*	*Sorbus*	*Arbutifolia*
Nyssa	*sylvatica*	*Quercus*	*nigra*	*Spartina*	*Alterniflora*
Oenothera	*biennis*	*Quercus*	*stellata*	*Spartina*	*Patens*
Oenothera	*fruticosa*	*Quercus*	*virginiana*	*Specularia*	*Perfoliata*
Oenothera	*laciniata*	*Rhus*	*copallina*	*Spergularia*	*Marina*
Opuntia	*compressa*	*Rhus*	*radicans*	*Sphenopholis*	*Obtusata*
Osmunda	*regalis*	*Robinia*	*pseudo-acacia*	*Spiranthes*	*Vernalis*
Panicum	*amarum*	*Rubus*	*argutus*	*Strophostyles*	*Helvola*
Panicum	*amarulum*	*Rumex*	*acetosella*	*Strophostyles*	*Umbellate*
Panicum	*dichotomifloru*	*Rumex*	*crispus*	*Suaeda*	*Linearis*
Panicum	*lanuginosum*	***Ruppia***	***maritima***	*Teucrium*	*Canadense*
Panicum	*scoparium*	*Sabatia*	*stellaris*	*Thelypteris*	*Palustris*
Panicum	*sphaerocarpon*	*Sagina*	*decumbens*	*Trachelospermum*	*Difforme*
Panicum	*virgatum*	*Salicornia*	*bigelovii*	*Triplasis*	*Purpurea*
Parthenocissus	*quinquefolia*	*Salicornia*	*europaea*	*Typha*	*Angustifolia*
Paspalum	*dilatatum*	*Salicornia*	*virginica*	*Typha*	*Latifolia*
Paspalum	*floridanum*	*Salix*	*nigra*	*Ulmus*	*Americana*
Paulownia	*tomentosa*	*Salsola*	*kali*	*Uniola*	*Laxa*
Persea	*palustris*	*Sambucus*	*canadensis*	*Uniola*	*Paniculata*
Phragmites	*communis*	*Samolus*	*parviflorus*	*Vaccinium*	*Atrococcum*
Physalis	*viscosa*	*Sassafras*	*albidum*	*Vaccinium*	*Corymbosum*
Phytolacca	*americana*	*Scirpus*	*americanus*	*Verbascum*	*Thapsus*
Pinus	*taeda*	*Scirpus*	*cyperinus*	*Verbesina*	*Occidentalis*
Pluchea	*purpurascens*	*Scirpus*	*robustus*	*Veronica*	*Serpyllifolia*
Poa	*annua*	*Sesuvium*	*maritimum*	*Vitis*	*Aestivalis*
Polygonum	*glaucum*	*Setaria*	*geniculata*	*Vitis*	*Rotundifolia*
Polygonum	*hydropiperoides*	*Setaria*	*magna*	*Woodwardia*	*Areplata*
Polypogon	*monspeliensis*	*Sisyrinchium*	*angustifo*	*Xanthium*	*Strumarium*
Populus	*alba*	*Smilax*	*bona-nox*	*Yucca*	*Filamentosa*
Prunus	*maritima*	*Smilax*	*glauca*	*Zanthoxylum*	*clava-hercules*
Prunus	*serotina*	*Smilax*	*rotundiflora*	***Zostera***	***Marina***

In Figure 1.7 through Figure 1.10, SAV locations are mapped in the VCR. Each map contains the extent of SAV for a designated year and location (Quinby, Inlet, Cobb's Island, or Ship Shoal Inlet). These maps were developed by the Virginia Institute of Marine Science (VIMS, 2009).

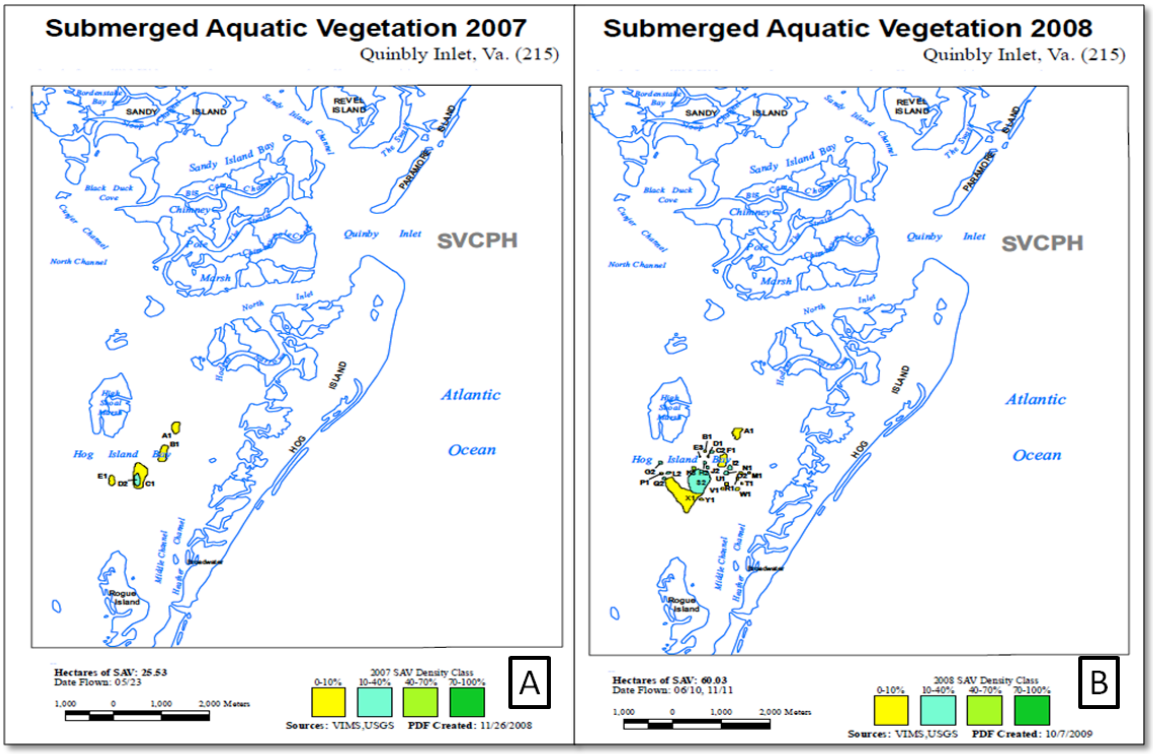

Figure 1.7. SAV Locations-Quinby Inlet, VA. (A) 2007. (B) 2008.

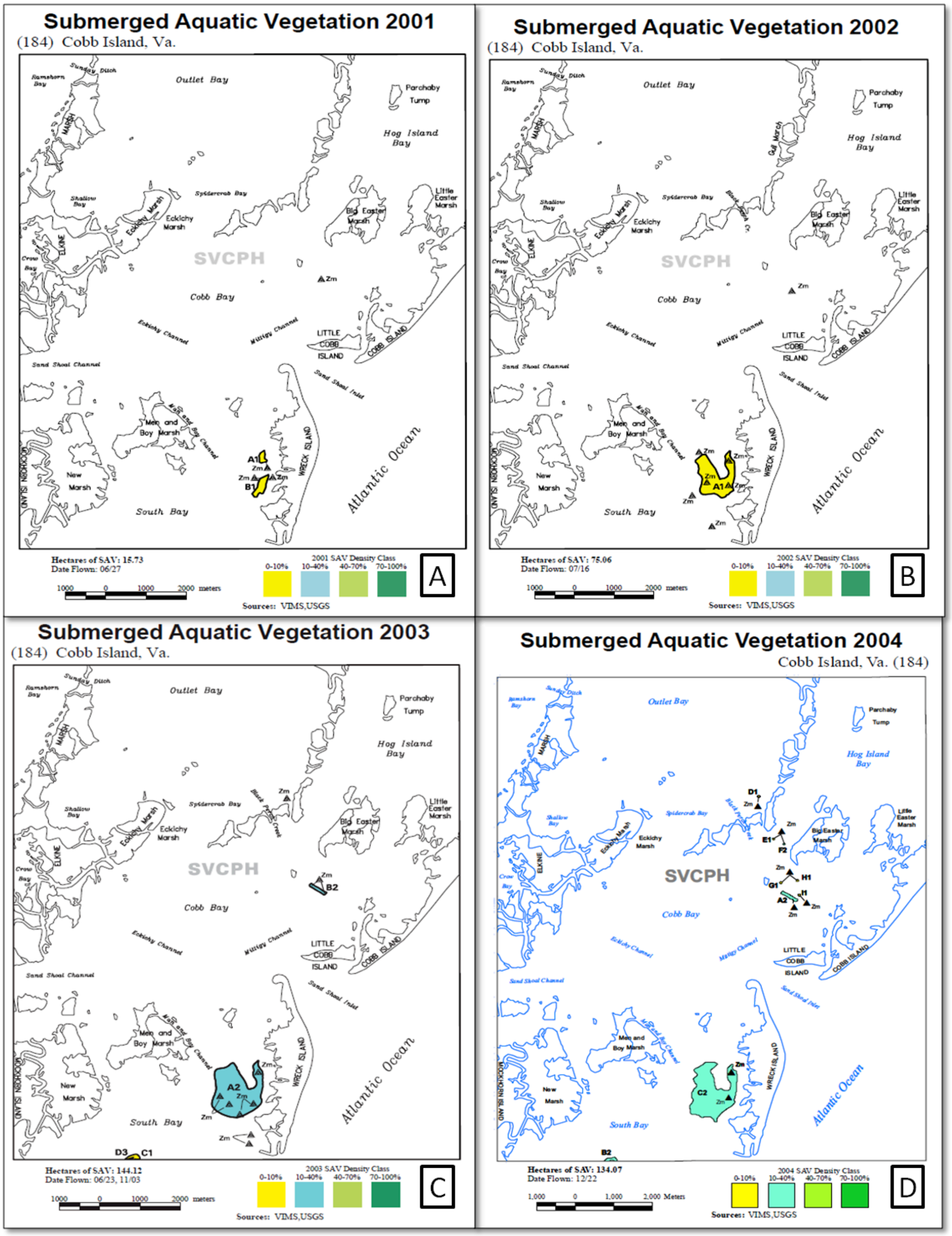

Figure 1.8. SAV locations Cobb Island, VA. (A) 2001. (B) 2002. (C) 2003 (D) 2004.

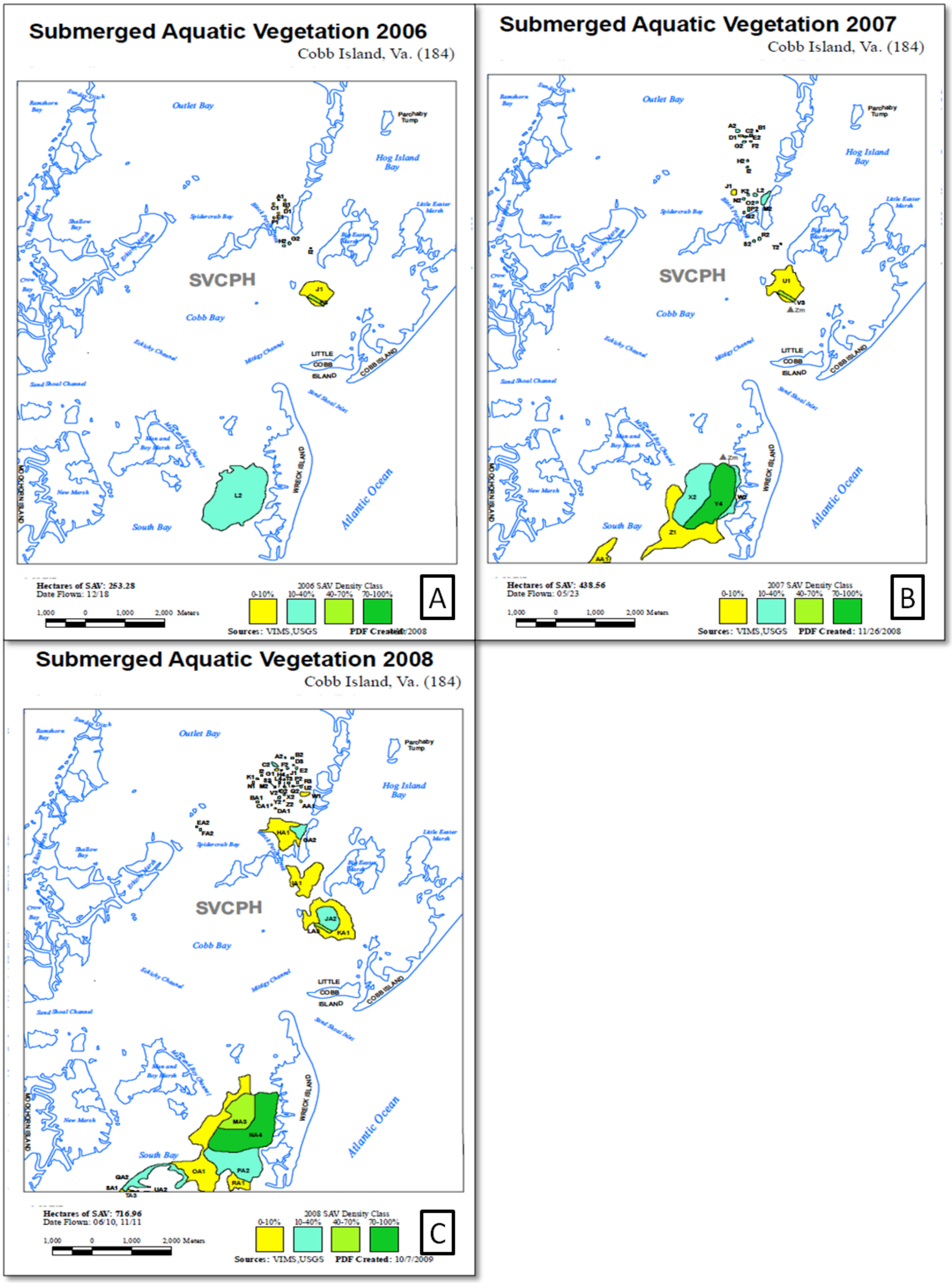

Figure 1.9. SAV locations, Cobb Island, VA. (A) 2006. (B) 2007. (C) 2008.

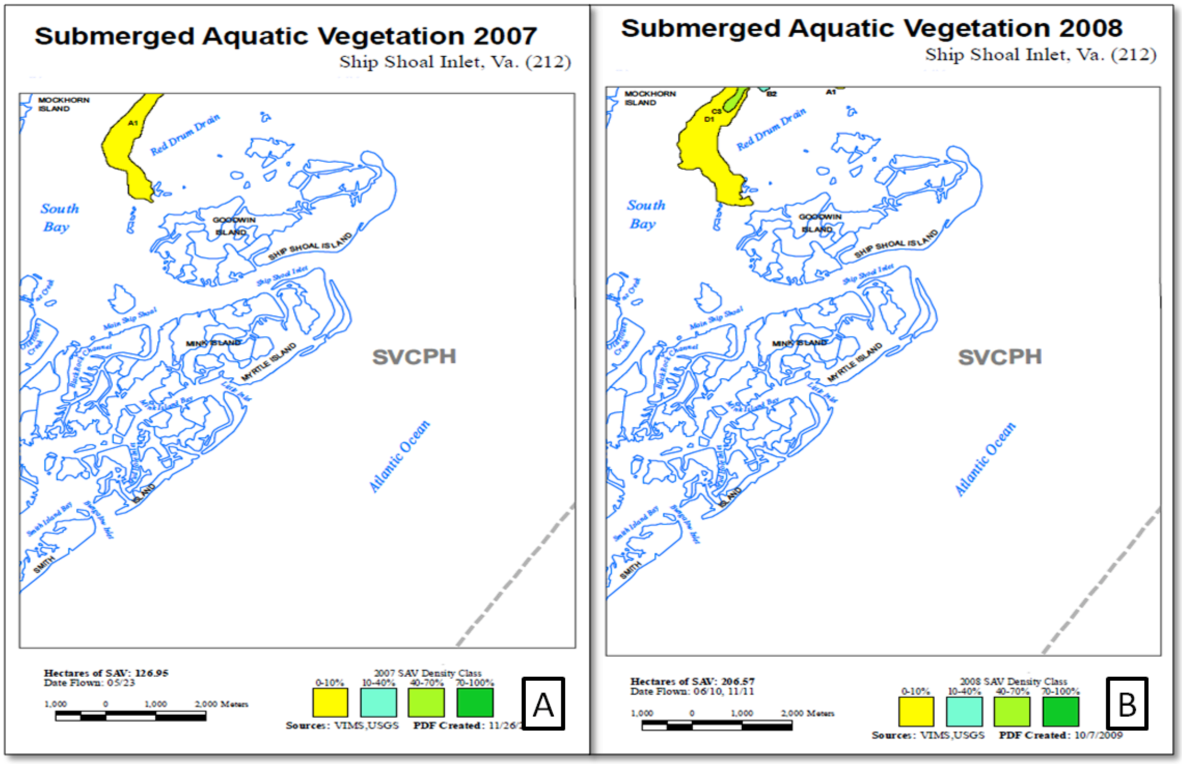

Figure 1.10. SAV locations, Ship Shoal Inlet. (A) 2007. (B) 2008.

2 Project Archive

2.1 General Information

Remote sensing campaigns at NRL are of great importance since they are being conducted at various coastal sites and allow the collection of large scale (1:5,000) data. The archived datasets are crucial to generating useful relationships among California Bearing Ratio (CBR), a standard index of soil shear strength, and other fundamental material properties for soils, especially in selecting favorable littoral penetration points. CBR is derived from penetration tests that measure the pressure required to penetrate the soil. The USMC uses CBR to determine the load-bearing capacity of soils used for building roads and expeditionary airfields. Harder surfaces will have higher CBR ratings. In general, a CBR of 3 equates to tilled farmland, a CBR of 4.75 equates to turf or moist clay, while moist sand may have a CBR of 10. High quality crushed rock has a CBR over 80. Table 2.1 displays CBR values and material descriptions of various surface types (WAPA, 2002).

Table 2.1. CBR value and material description. The DCP was used to provide an estimate of CBR.

CBR Value	Material Description/Material Type
1 - 5	Organic Soils (Tilled Farmland ≈3)
3 - 10	Clay Soils (Turf or Moist Clay ≈4.75)
3 - 15	Silty Soils
5 - 40	Sandy Soils (Moist Sand ≈10)
20-100	Crushed Stone

Archiving this type of data from NRL's remote sensing campaigns complements existing databasing efforts such as the small scale (1:5,000,000) United Nations Food and Agriculture Organization's world soils map (see FAO-UNESCO 1974) and the medium scale (1:250,000) Soil and Terrain Database (see ISRIC 2004), and relating this and other associated geotechnical data to *in situ* spectral measurements and remote sensing data is the basis of NRL's approach to remote retrieval of soil bearing properties.

2.2 Geodatabase

A geodatabase is a collection of geographic datasets made for use with ArcMap or other geographic information systems (GIS) such as ArcGIS Explorer. Geographic dataset types contained in the VCR'07 geodatabase are feature classes, attribute tables, and raster datasets. Feature classes share the same geometry type, such as point, line, or polygon, same spatial reference and same attributes. An example feature class contained in the VCR'07 would be "VCR_GPS_WORK_LOCATIONS" which is a shapefile containing a point for each GPS marked work site. A shapefile is a vector storage data format containing the location, shape, and attributes of geographic features. Attribute tables are tabular files which contain information about a shapefile. A raster dataset is an image that contains equally sized cells arranged in rows and columns and comprised of single or multiple bands. Each cell contains an attribute value and

location coordinates. Raster datasets contained in the VCR'07 geodatabase are raster catalogs (individual raster files grouped) of each day's CASI quicklook images, a raster catalog of manipulated CASI images of each island visited, and each quicklook CASI image obtained during the VCR'07 campaign. Quicklook images are JPEG (three-band) format raster images of the HSI obtained during VCR'07. Please refer to Appendix C for maps containing the quicklook images.

The GIS software packages used in the development of NRL CODE 7232 geodatabases are ESRI's ArcGIS Explorer and ESRI's ArcGIS Desktop (ArcView license). Both can be used to view the geodatabase, but there are organizational differences in data structure between the two GIS. The primary software package to view the geodatabase would be ArcGIS, as it allows for analysis and interpretation capabilities much greater than ArcGIS Explorer. ArcGIS Explorer is a free GIS software package based on ESRI's commercial ArcGIS product series. The software package facilitates the input of local data as well as data from ESRI. Shapefiles made in ArcGIS can be brought into the ArcGIS Explorer. ArcGIS users may find some compatibility issues with the ArcGIS Explorer, but in general, data created in ArcGIS can be brought into ArcGIS Explorer. Keyhole markup language (.kml) and keyhole markup language-zipped (.kmz) files made in Google Earth can be imported into ArcGIS Explorer. ArcGIS Explorer software package is available for download (ESRI, 2009).

Data obtained during VCR'07 is organized onto 2TB disk drives. The VCR'07 database is being organized to follow similar formats of other databases developed by NRL (HALE, HI-HARES, and TS'09). On the 2TB disk drive, the data are organized into folders of similar data type, which comprises the geodatabase. Figure 2.1 displays the folder hierarchy that was designed for the VCR'07 database. In the figure, the VCR'07 database (VCR_GD) contains seven folders (Attribute Data, GIS Data, Metadata, Misc, Products, User Manual Information, and VCR_GD.gdb) and three files (VCR_ALL Data.xls, VCR_GD.mxd, and VCR_GD.nmf) at the top level. The Attribute Data folder contains sub-folders of each type of data collected during the VCR'07 campaign. Most folders contain tabular data for each day that data were collected. The tabular information is combined into *VCR_ALL_DATA.XLS* with each tab containing different types of data. In the Attribute Data folder, non-tabular data are mainly contained in the folders HSI and Photographs. These two folders contain raster images that can be opened via ITT's ENVI and Microsoft® Windows Picture and Fax Viewer, respectively. The GIS Data folder contains the ArcGIS Explorer 900 program and associated files, *KML/KMZ* files used for interoperability with Google® Earth, *mxd* files, raster files, and various shapefiles. The raster files and shapefiles in the GIS Data folder are files which have been gathered from multiple sources. Files residing in these folders are the preliminary shapefiles which have not been exported into "gdb" file format via ArcCatalog. The Metadata folder contains FGDC documentation about shapefile, raster, and geodatabase creation. The Misc folder contains miscellaneous files. The Products folder contains raster, and text products created from the attribute data. The data report resides in the Text subfolder to the Products folder. The User Manual Information folder contains documentation about retrieving data and navigating the database and geodatabase. When navigating via Windows® Explorer the VCR_GD.gdb (File Geodatabase) appears as a folder, but when navigating via ArcCatalog the VCR_GD.gdb appears as geodatabase icon. The format of the VCR_GD.gdb is a File Geodatabase.

VCR_GD

Folder/File	Description
• **Attribute Data** • ASD • Ceptometer • DCP • DiveSpec • GPS • HSI • LWD • Photographs • Soil • Tide Data	Contains all attribute data collected during the field campaign. Data is broken down by folder into data type. Each data type this then broken down by folder by date.
• **GIS Data** • ArcGIS Explorer • KML/KMZ • MXDS • Rasters • Shapefiles	Contains all shapefiles, rasters, not exported to .gdb format as well as ArcGIS Explorer documents and program files, kml and kmz files used with Google Earth, and ArcMap documents (mxd format).
• **Metadata**	FGDC documentation, etc.
• **Misc**	Miscellaneous files
• **Products** • Bathymetry • Text • Trafficability • Vegetation	Various products: Bathymetry: ENVI files and images. Text: Contains presentations, data reports. Trafficability: ENVI files and images.Vegetation: ENVI files and images
• **User Manual Information**	User manual documents
• **VCR_GD.gdb**	Geodatabase folder (seen in ArcCatalog)
• *VCR_ALL_Data.xls*	Excel spreadsheet containing all data
• *VCR_GD.mxd* • *VCR_GD.nmf*	ArcMap (.mxd) and ArcGIS Explorer (.nmf) Files

Figure 2.1. Typical organization of data on drive. Top level folders are shown in bold, while sub-folders are shown with non-bold type. Italicized names indicate files. Descriptions of each folder/file are listed on the right hand column.

To access the geodatabase via Windows® Explorer, click the *VCR_GD.mxd* (opens in ArcMap) or *VCR_GD.nmf* (opens in ArcGIS Explorer). Figure 2.2 displays a screen capture of the ArcMap version of the VCR'07 geodatabase.

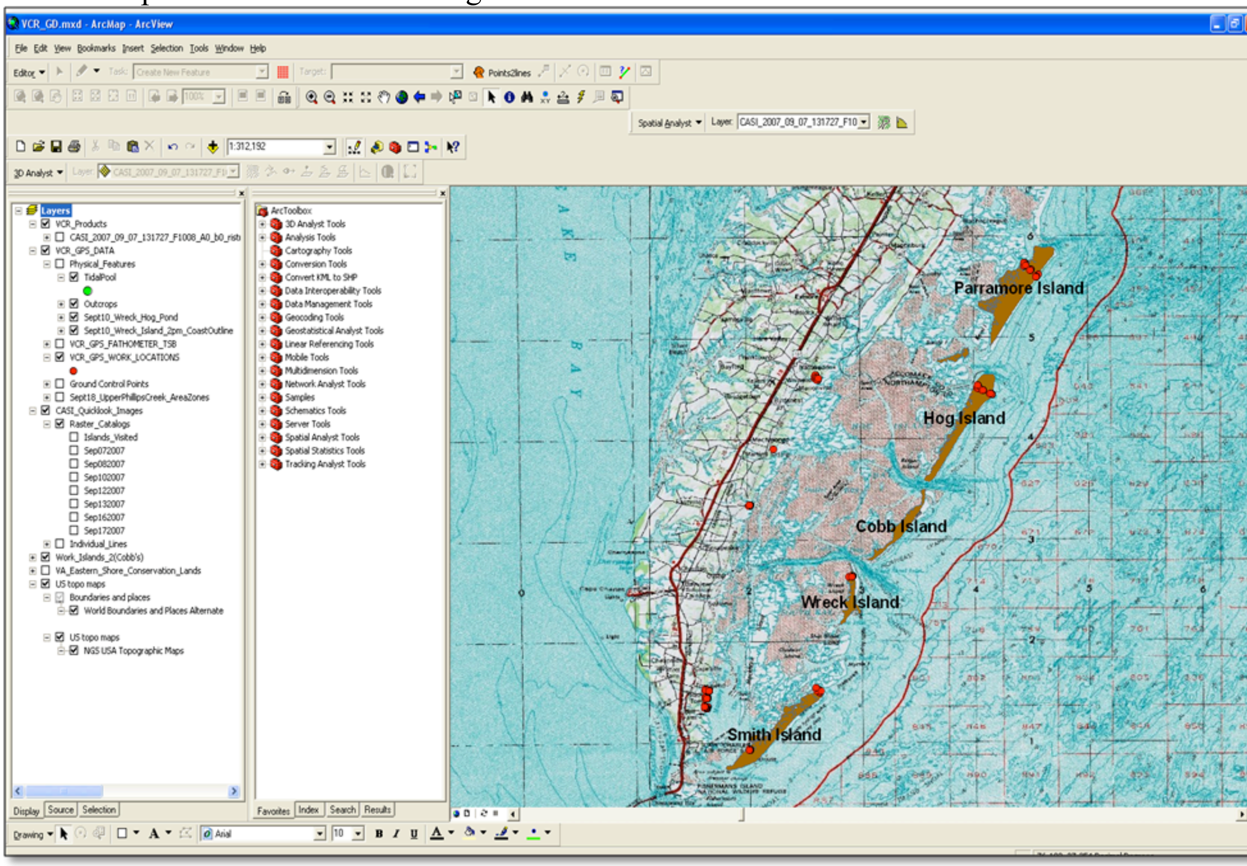

Figure 2.2. Screen capture of VCR'07 geodatabase viewed in ArcMap.

Data can be accessed via ArcMap by utilizing the identify tool  located on the toolbar above the ArcMap map viewer section. By clicking the identify tool and clicking on a shapefile, the attribute information can be seen of the shapefile feature (point, line or polygon). Figure 2.3 describes how to access hyperlinked data in a feature's attribute information. In the figure, by clicking on the identify tool (A) and clicking a GPS point (B), a window containing the point's attribute information (C) is displayed. The attribute information contains hyperlinked data (yellow icon) and when this data is clicked, a photograph, spreadsheet, or document opens in another window. More information on how to navigate and access data in the geodatabase is described in Appendix J.

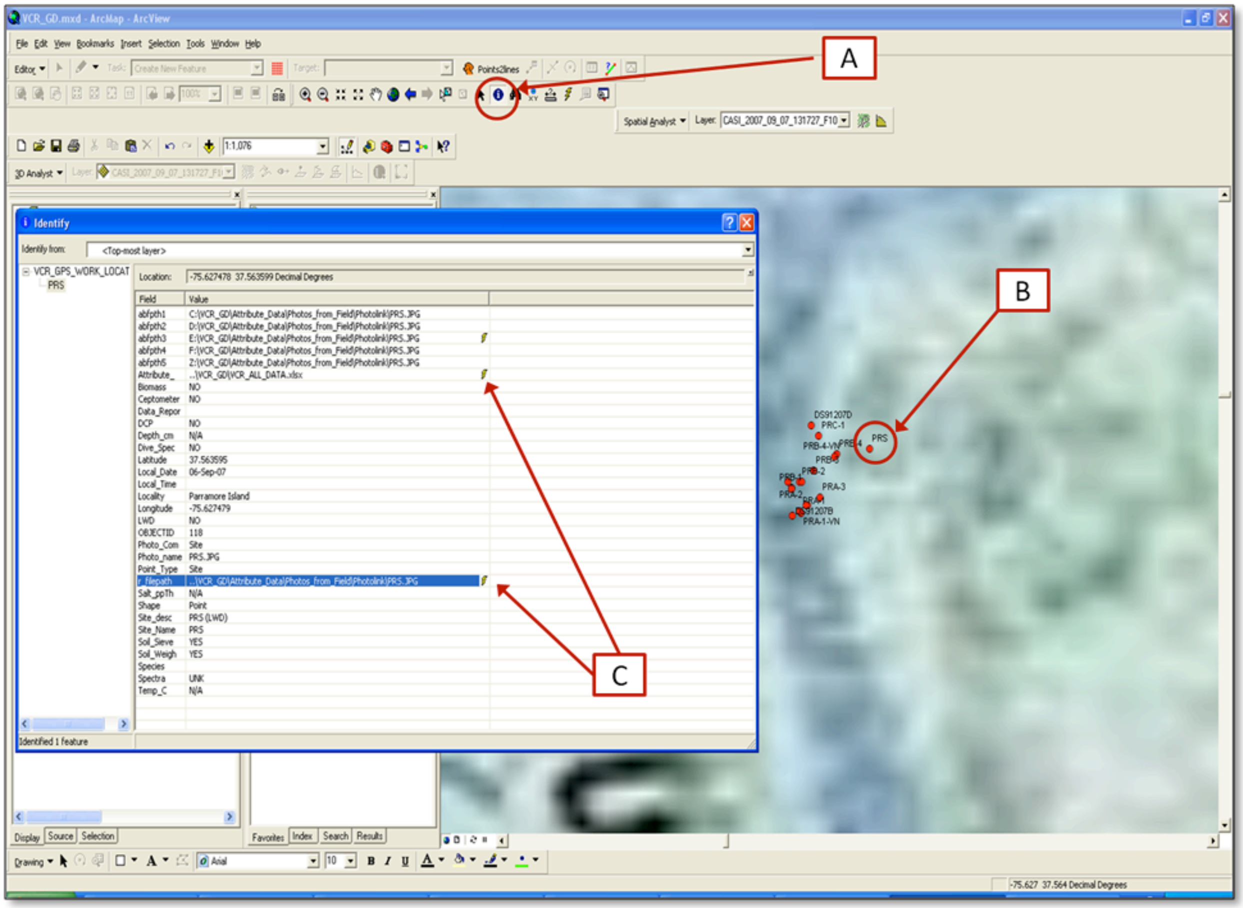

Figure 2.3. Accessing hyperlinked data via the identify tool in ArcMap. (A) Click on identify tool. (B) Click on a point, polygon, or line feature. (C) Click on yellow hyperlink icon to access hyperlinked data.

3 Visualization

Trafficability is the ability of the terrain to support the movement of vehicles and people. Some of the important factors are vegetation density, bearing capacity, and shear strength of the soil. Analysis was conducted to classify HSI to represent trafficability for the VCR's "littoral penetration areas." A littoral penetration area is of sufficient size to conduct unrestricted sea, air, and land operations. Measurements were binned into excellent, good, fair, poor, or bad categories. The bathymetry of the littoral environment was extracted from HSI in order to complement trafficability maps.

3.1 Spectra Collection

The ASD-Full Range (FR) spectrometers record radiance in the 0.35-2.5 micron range every 1nm with a 2nm spectral resolution; results were converted to units of reflectance by comparing samples with those obtained from a white reference Spectralon® plaque. Spectralon® provided an approximately 99% reflecting surface, and is a standard used in the spectral remote sensing community. In our sampling strategy, two alternating sets of 30 samples each of white plaque and substrate were averaged to reduce noise and vulnerability to variations in solar illumination during the period of measurement. For SWIR measurements, a large number of measurements are desirable because of lower photon counts in this portion of the spectrum. A variety of configurations were used depending on conditions, but the preferred configuration consisted of two tripods, one for the spectrometer fore-optics and the other for the white Spectralon ® reference plaque. The spectrometer fiber optic cable was mounted in a pistol grip on one tripod in a nadir-looking configuration, while the Spectralon® plaque was mounted on a second tripod and rotated into and out of the field of view of the spectrometer to allow rapid collection of white plaque and specimen radiance measurements needed for the reflectance ratio. To maintain consistency in leveling and viewing geometry, alternating specimen and reference spectral samples were collected.

Spectral measurements were taken of the *in situ* geotechnical measurement locations, as well as *in situ* vegetation sources. In addition, other spectral measurements were focused on water column properties and retrievals for mapping purposes. In Section 4.1.4, we describe details of shallow bathymetry spectroscopy undertaken during the VCR'07 campaign. Figure 3.1displays various ASD spectroradiometer configurations encountered during the VCR'07 campaign. Spectra graphs and location photographs can be seen in Appendix E.

Figure 3.1. Spectra collection configurations. (A) Site spectra collection using two tripods. (B) Site spectra collection using one ASD and hand-held Spectralon® plaque. (C) Shallow water bathymetry collection using two tripods. (D) *In situ* vegetation collection using one ASD and handheld Spectralon® plaque.

In addition, bottom reflectance measurements were also taken by scientific divers affiliated with the American Academy of Underwater Sciences (AAUS). The divers were deployed using small craft and used an underwater spectrometer in shallow coastal lagoon areas, in coastal inlets, and just outside the surf zone. Another team of scientists collected in-water optical data in the coastal lagoons, inlets, and ocean aboard a third vessel.

3.1.1 Site Spectra. Spectroscopy was the most labor intensive component of the *in situ* measurement program, with the typical measurement paradigm consisting of two simultaneous transects of spectral measurements with the two ASD-FR spectrometers. The geotechnical instrument team moved back and forth between the two spectral transects collecting geotechnical data immediately after spectral data collection at each station.

3.1.2 Shallow Water Bathymetry. Spectral measurements were taken of the water column on two days at two locations. Shallow water bathymetry spectral measurements were taken at Parramore Island on 12 September, 2007, and on Wreck Island on 13 September, 2007. The methodology involves measuring the water depth with a yard stick and taking spectral

measurements of substrate and white sampling, repeating the process until bare substrate or inundation to the 1m water level. The geographic position of each location is seen from an altitude of 2000m in Figure 3.2. The Parramore Island site was situated on the west side of the barrier island and the sampling location was accessed from Clubhouse Gulf, an extension of Horseshoe Lead. The Wreck Island location was situated at the northern tip of the island at a location south of South Shoal Inlet and north east of the South Bay Tidal Flat. Spectra for each location are plotted in Appendix E.

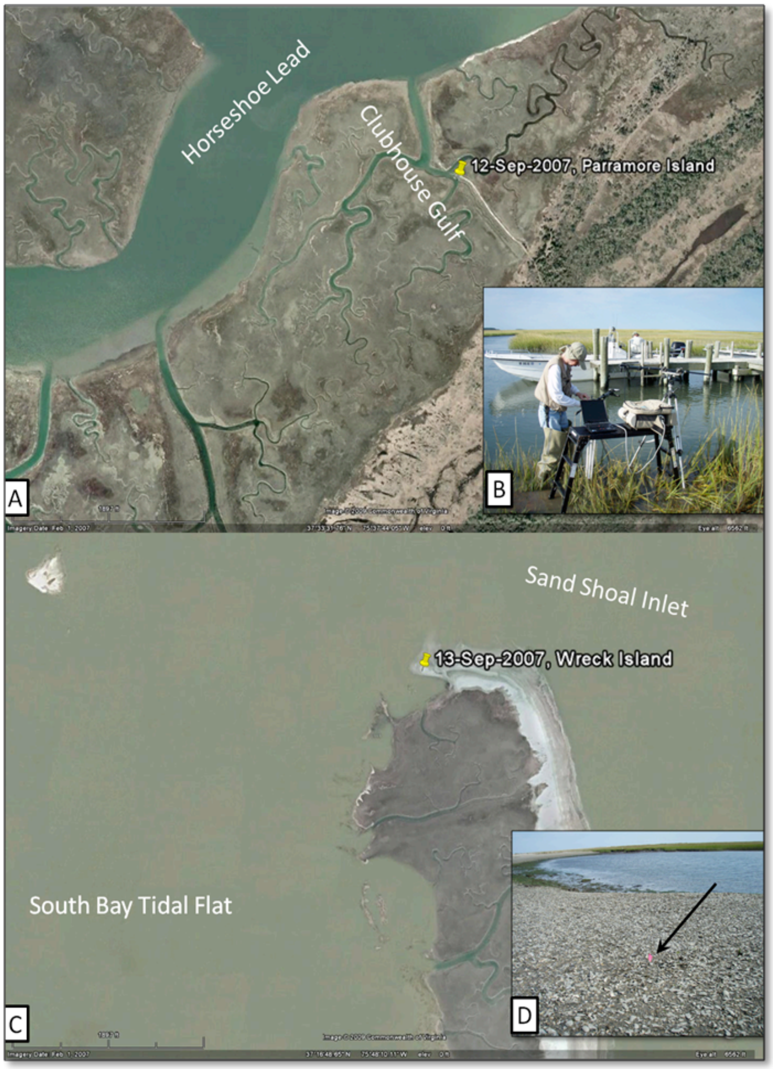

Figure 3.2. Shallow water bathymetry locations viewed in Google ® Earth. (A) Parramore Island imagery from an altitude of 2000m. (B) Photograph of location. (C)Wreck Island imagery from an altitude of 2000m. (D) Photograph of location.

3.1.3 Study Site Vegetation. As well as taking spectra in synchronization with geotechnical measurements, spectra were collected for vegetation covering a particular sampling station in order to develop vegetation models. This type of spectral measurement (canopy spectral reflectance measurement) is different from the leaf optic spectral reflectance measurement methodology. Spectroscopy of vegetation in the study area involved using ambient light while leaf optic spectroscopy involved obtaining a sample in the field, analyzing this sample under laboratory conditions, and using an attached apparatus with a light source. The lower left panel

(D) in Figure 3.1 illustrates the use of the ASD spectroradiometer to analyze vegetation at the sampling location.

3.1.4 Underwater Spectrometry. Bottom reflectance was measured at two locations (Smith Island and Parramore Island) by two divers affiliated with the AAUS. The bottom reflectance was measured using a NightSea DiveSpec® Underwater Spectrometer, an instrument which records in three modes, i.e., reflectance relative to reference surface, fluorescence stimulated by blue light, and ambient light (Mazel, 2007). The model used in VCR'07 (Figure 3.3) collects in a wavelength range 360-800nm with spectral resolution of 2nm. Data were collected at Smith Island on 10 September and at Parramore Island on 12 September. Only a few sites of usable data were collected at Parramore due to instrument malfunction.

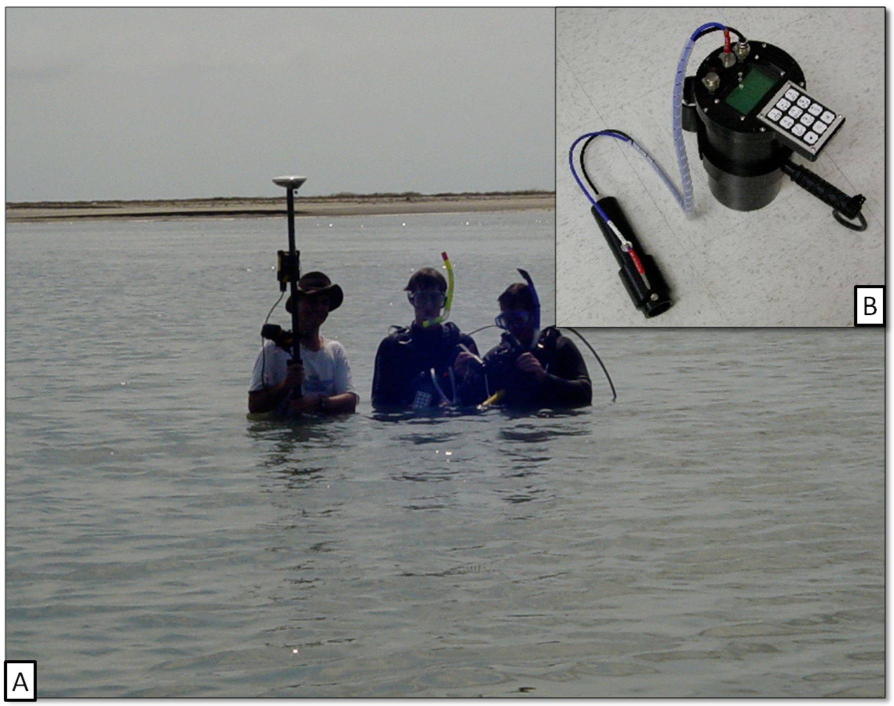

Figure 3.3. Underwater spectrometry. (A) Scientific divers conducted underwater spectrometry in shallow water (GPS also pictured) with field survey team. (B) NightSea DiveSpec® unit.

3.2 Light Weight Deflectometer (LWD)

The Zorn ZFG2000 Light Drop Weight Tester (Figure 3.4) is one of a class of instruments known as a LWD. The Zorn LWD consists of an accelerometer attached to steel plate of diameter 300mm, and a mountable rod with 10kg weight that is repeatedly dropped on the accelerometer. Three pulses are measured and stored on an electronic recorder and memory card, recording the deflection of the plate on the ground in response to the dropping of the 10kg weight from a known reference height.

The 10kg weight is dropped three times to achieve a stable estimate of the deflection of the plate as a function of time; these curves are used to estimate the dynamic modulus of rigidity (Evd) in mega-Newtons per square meter (MN/m^2); the system also records the average deflection in time divided by its average velocity (s/v ratio). The units of this ratio are milliseconds, and the quantity gives an estimate of compression. The Zorn LWD bases the retrieval of Evd on a half-space model (Zorn, 2005).

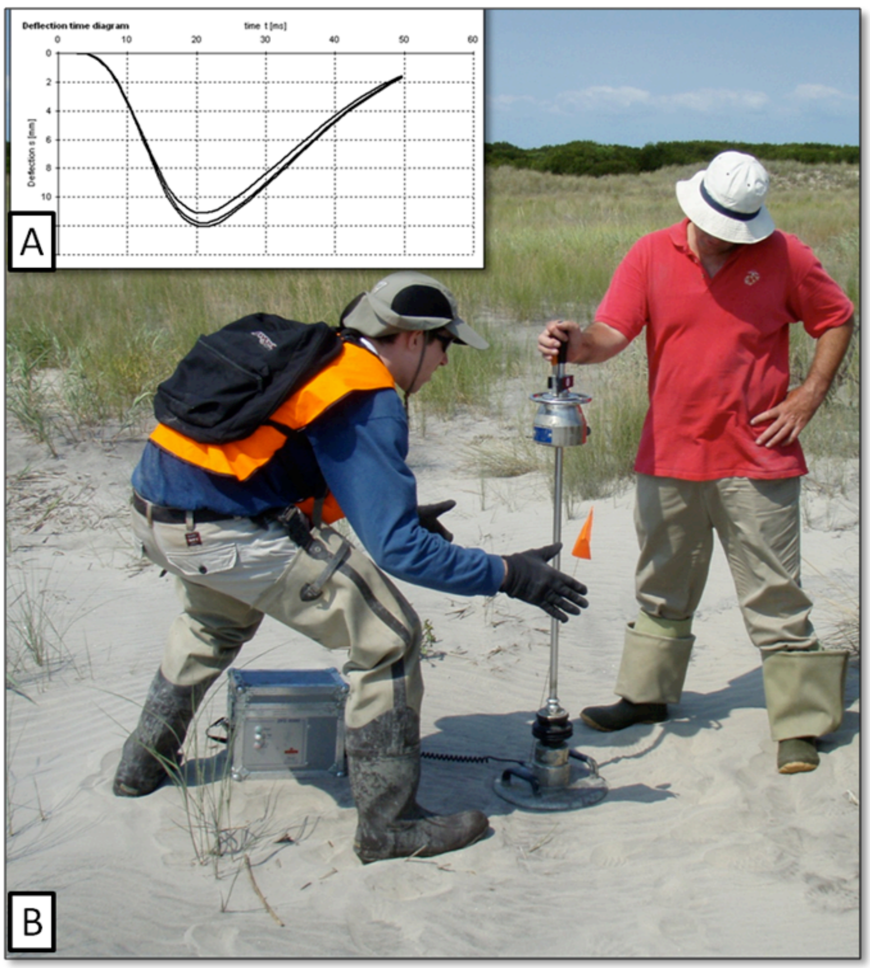

Figure 3.4. The LWD being used to measure dynamic modulus during the VCR'07 campaign. (A)The three pulses showing deflection (mm) as a function of time (ms) used in estimating Evd (B) Light-weight deflectometer (LWD) used to measure dynamic modulus of rigidity, Evd, which is estimated from three successive drops of a 10kg weight along a steel rod attached to a base plate with an embedded accelerometer.

3.3 Dynamic Cone Penetrometer (DCP). The Kessler DCP (Figure 3.5) consists of either a 4kg or 8kg weight attached to a rod with a steel drive rod and cone attached to the end. During VCR'07, the 4kg weight was used exclusively because of the softer, saturated characteristics of many of the soils studied during the campaign. The weight is repeatedly dropped on the drive rod, and with each blow the distance the cone advances into the soil is recorded. This record is translated into a measure of shear strength as a function of depth using a standard index known as the California Bearing Ratio (CBR), an existing standard in the U.S. in the civil engineering community. When building military roads and airfields, CBR is used to evaluate the strength of cohesive materials having maximum particle sizes less than 19 mm. Further information and DCP data can be viewed in the CBR Appendix (Appendix G).

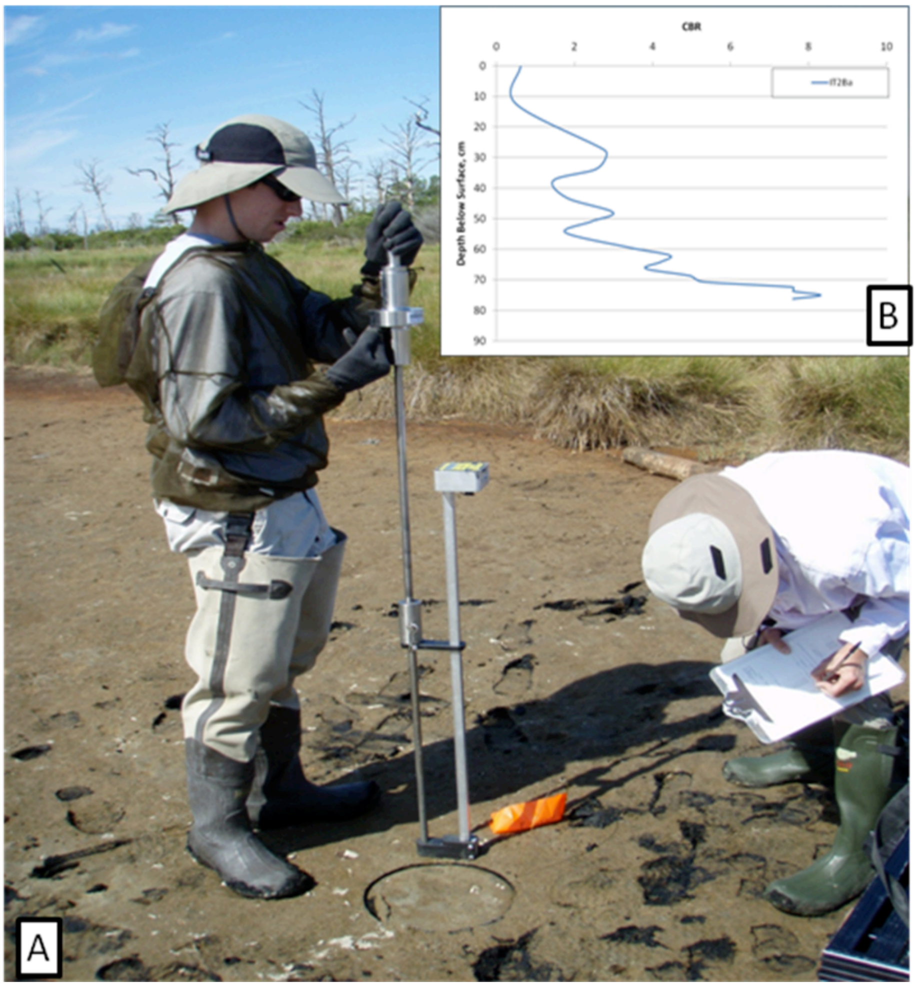

Figure 3.5. A dynamic cone penetrometer (DCP) is used to estimate California Bearing Ratio (CBR). (A) DCP used to measure shear strength during the VCR'07 campaign; shown: a transect site on Hog Island, VA, Sept. 7, 2007. (B) Depth below surface (y-axis) is plotted verse CBR (x-axis).

3.4 Soil Analysis. A grab sampler (Figure 3.6) was used to extract a standard core from each sample position to obtain a representative sample of the first 7cm inches of the substrate (the approximate dimensions of the grab sampler: were 7cm diameter with a height of 7.6cm). Each sample was returned to the ABCRC where the percentage moisture content was obtained by weighing the substrate before and after drying. The dried sample was passed through a sieve shaker set to obtain grain size profiles in the range between 27-600 microns (Figure 3.7). All particles passing the 27 μm sieve were collected in a bottom pan. Substrate collection samples represented typical coastal soil types representative of the VCR study area, including beach, salt pans, peat outcrops, mudflats, and salt marsh and tidal creek environments.

Figure 3.6. Grab sampler in use extracting core sample.

3.4.1 Soil Moisture Content. Core samples were obtained via the grab sampler described above and put directly into soil containers for later analysis at the ABCRC. Samples were stored in a refrigerator prior to analysis in order to prevent soil moisture loss. Each sample was weighed prior to drying and again after drying via microwave. The soil moisture is determined by a similar protocol found in the Army Field Manual for materials testing (FM 5-472, NAVFAC MO 330,AFJMAN 32-1221(I)) which follows the microwave oven method for determining soil moisture content (ASTM D 4643-87) (Department of the Army, 2001; ASTM,2002). The soil's moisture content (in percent) is calculated as the ratio of the mass of the water contained in the soil to the mass of the dry soil and multiplied by 100 (Black, 1965; Schmugge, Jackson, McKim, 1980; Famiiglietti, 1998). More soil moisture information and data can be viewed in the Soil Properties Appendix (Appendix H).

3.4.2 Soil Grain Size. Grain-size analysis, which is among the oldest of soil tests, is used in soils classification and as part of the specifications of soil for airfields, roads, earth dams, and other soil-embankment construction. The standard grain-size analysis test (ASTM D 422-6) determines the relative proportions of different grain sizes as they are distributed among certain size ranges that are referred to as particle-size or grain-size distribution (ASTM, 1998). In order to grade the sample properly, the sieving operation used a Humboldt H4325 mechanical sieve shaker to obtain lateral, vertical, and jarring actions, which keep the sample moving continuously over the surface of the sieve. After sufficient shaking, the mass of each sieve size is determined on a scale or balance. Then, the total percentage of material passing each sieve is calculated. A photograph of the shaker and a soil sample separated into grain size distributions is displayed in Figure 3.7.

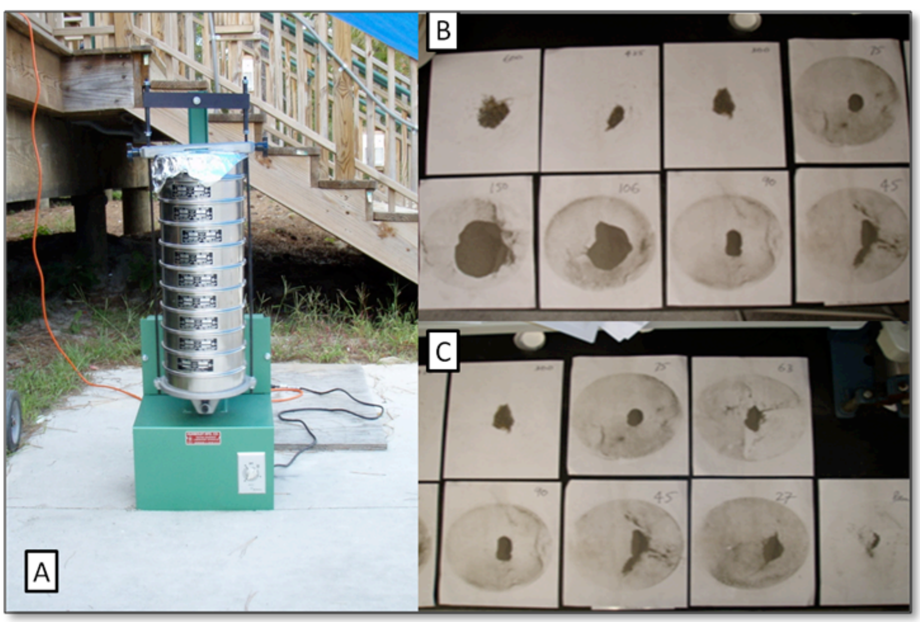

Figure 3.7. Grain size analysis was performed after drying and soil moisture calculations. (A) Soil shaker with sieves in operation. (B, C) After separation into grain size fractions, contents were weighed, and the amount for each grain size bin recorded for later correlation with spectral data and other geotechnical data.

After the soil sample is separated into similar grain sizes, each grain size portion is weighed and its percentage of the total sample is recorded. Figure 3.8 displays particle size along the *x*-axis while percent of total sample is seen along the *y*-axis.

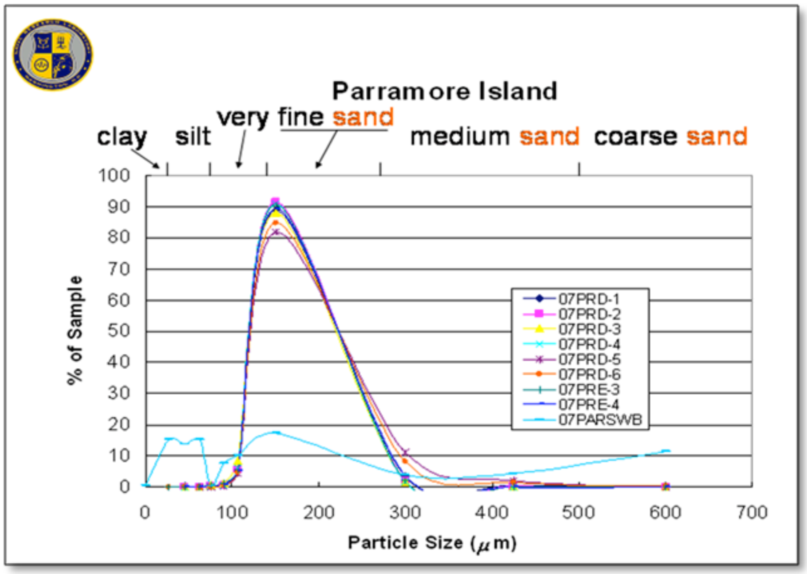

Figure 3.8. Grain size profile examples using the sieve analysis of Figure 3.7. The particle size grouping name is listed at the top.

3.5 Global Positioning System (GPS) Site Marking. Each site of data collection was marked with a Trimble® Pro-XH post-processing GPS unit (Trimble, 2007). The raw positional data was processed via the H-Star network of GPS base stations which allowed for greater positional accuracies. The positions were exported from the Trimble® Pathfinder Office program and a shapefile was developed. The shapefile indicates the position at which *in situ* data were taken and is used as the cal/val points for product development. Figure 3.9 displays the collection of GPS data as well as a product GPS shapefile.

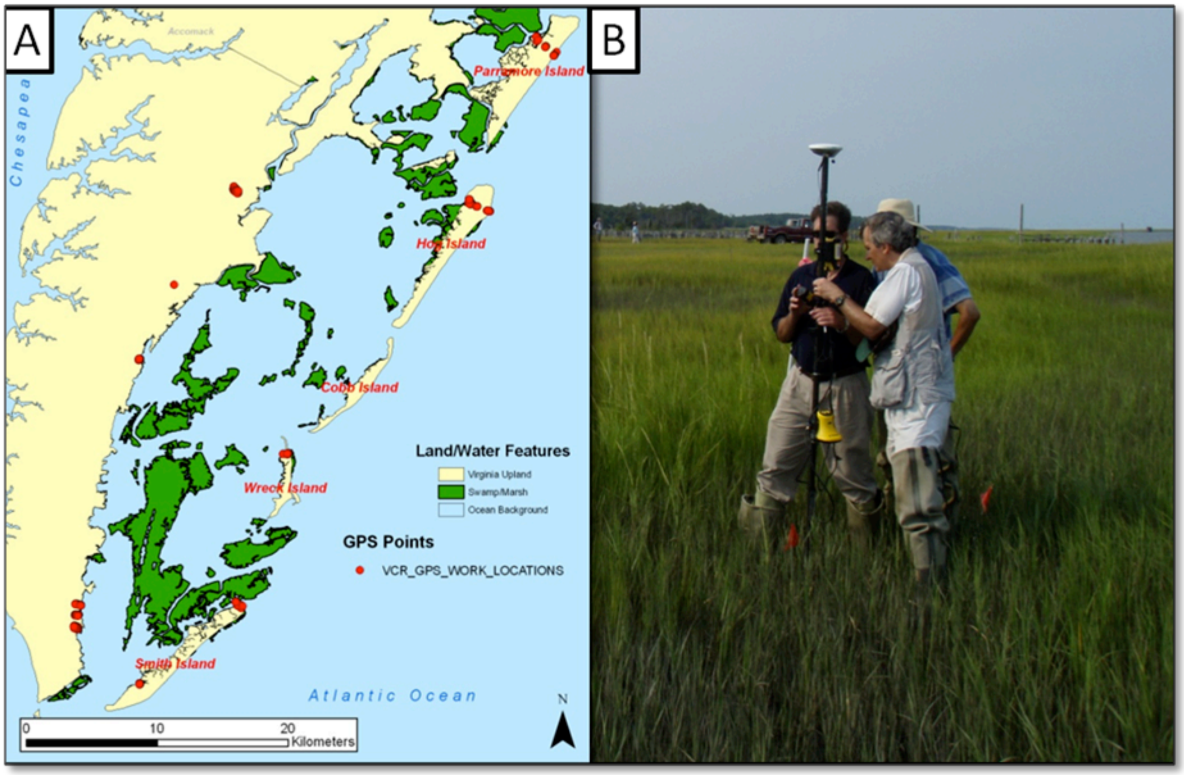

Figure 3.9. GPS data collection and resultant GPS point shapefile. (A) GPS shapefile (red dots) seen in a map figure. (B) Data collection of GPS location.

3.6 Bathymetry, Salinity, and Temperature (BST). During the VCR'07 effort, BST measurements were taken on two days; 10 September (Smith Island region) and 17 September (Wreck Island region). The bathymetry measurements were collected via a Vexilar® LPS hand-held sonar calibrated to the research boat's fathometer. The salinity and temperature were measured via an YSI® 30 salinity and temperature probe. Figure 3.10 displays a map of BST measurement locations and photographs taken during data collection.

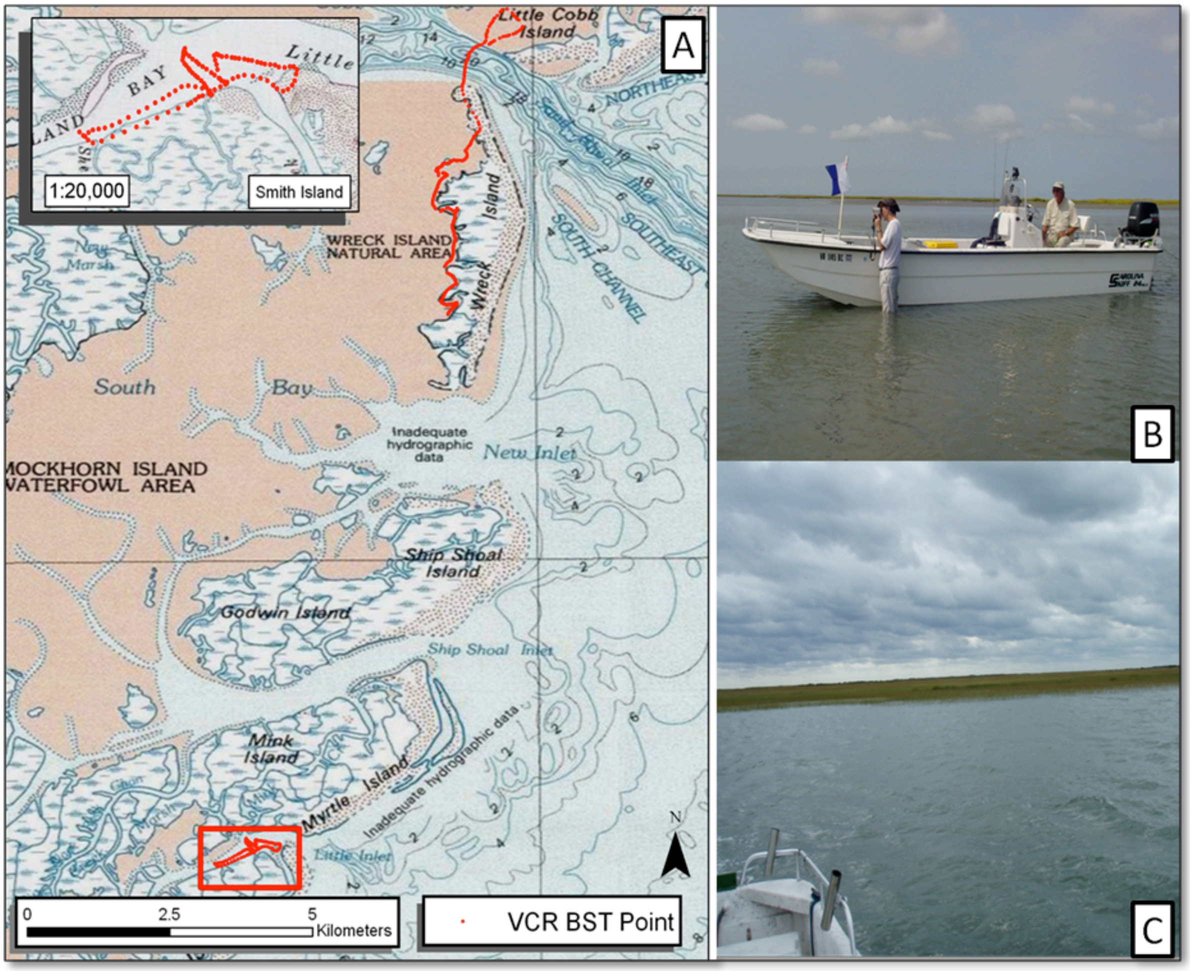

Figure 3.10. Bathymetry, Salinity, and Temperature (BST) measurement points during VCR'07. (A) Map of BST points taken during VCR'07. The insert seen at upper left represents area indicated by red square. (B) Carolina Skiff utilized for BST measurements. (C) Picture of Wreck Island from vessel.

3.7 Ground Control Points (GCPs). Ground control points are GPS marked positions with fixed referenced points that can be used for georeferencing remotely sensed images. The GCPs are usually taken at man-made structure locations, such as a building corner, or any other structure which visually contrasts from the background where it is situated. Usually GCPs are taken of well established locations which have existed over numerous years as this is done to standardize previous airborne imagery. In the VCR'07, GCPs were taken on 15 August at Cushman's Landing (dock) and on 16 September at Parramore Island (bridge). A map and Google® Earth images of GCP positions acquired during VCR'07 can be seen in Figure 3.11.

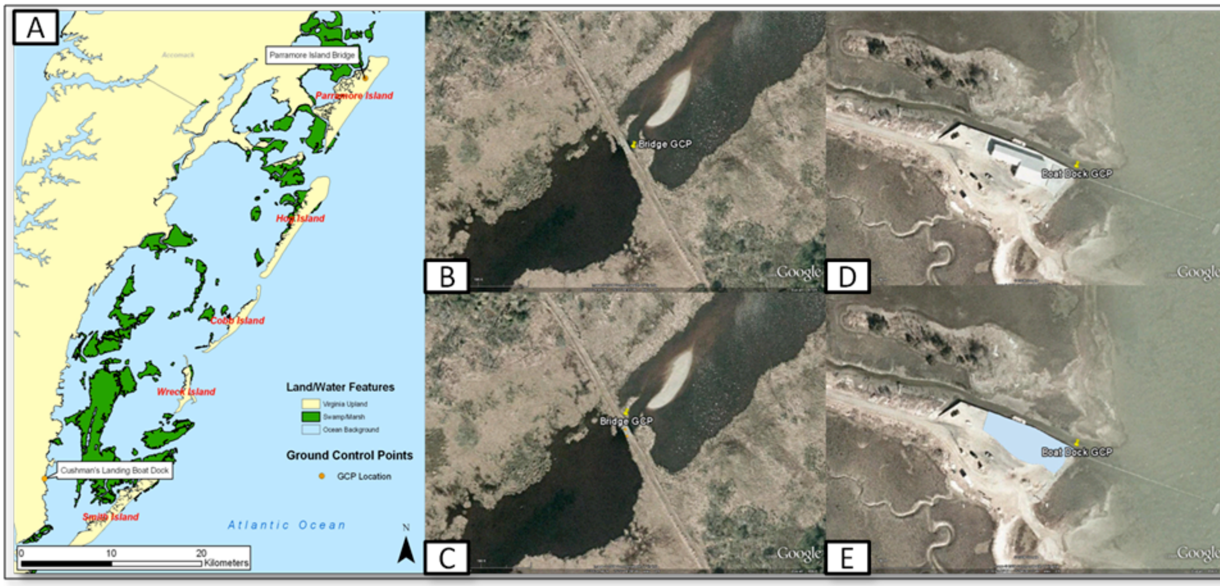

Figure 3.11. GCP positions taken during VCR'07. (A) Map. (B) Parramore bridge from 200m. (C) Parramore bridge with orange GPS points. (D) Boat dock from 200m. (E) Boat dock with GPS derived shapefile.

3.8 Biomass . Biomass measurements were collected from four sites on Smith Island on 5 September 2007 and from seven sites on Parramore Island on 6 September 2007. To collect biomass data, vegetation in a specified radius is cut and then weighed in order to determine vegetation density (Bachmann, Ramsey, Christian, et al, 2007). The density values are used to develop look-up tables to use with hyperspectral imagery. Biomass data is listed in Appendix K.

3.9 Ceptometer. A Ceptometer measures Photosynthetically Active Radiation (PAR) and Leaf Area Index (LAI). Ceptometer data were recorded via an AccuPAR LP-80 (Decagon Devices, 2007). The instrument has a 90cm probe which contains 80 sensors which measure PAR at a determined level above the canopy floor. Figure 3.12 illustrates the AccuPAR LP-80 being used at the VCR. Panel (A) shows the PAR sensors while panel (B) shows the instrument controls.

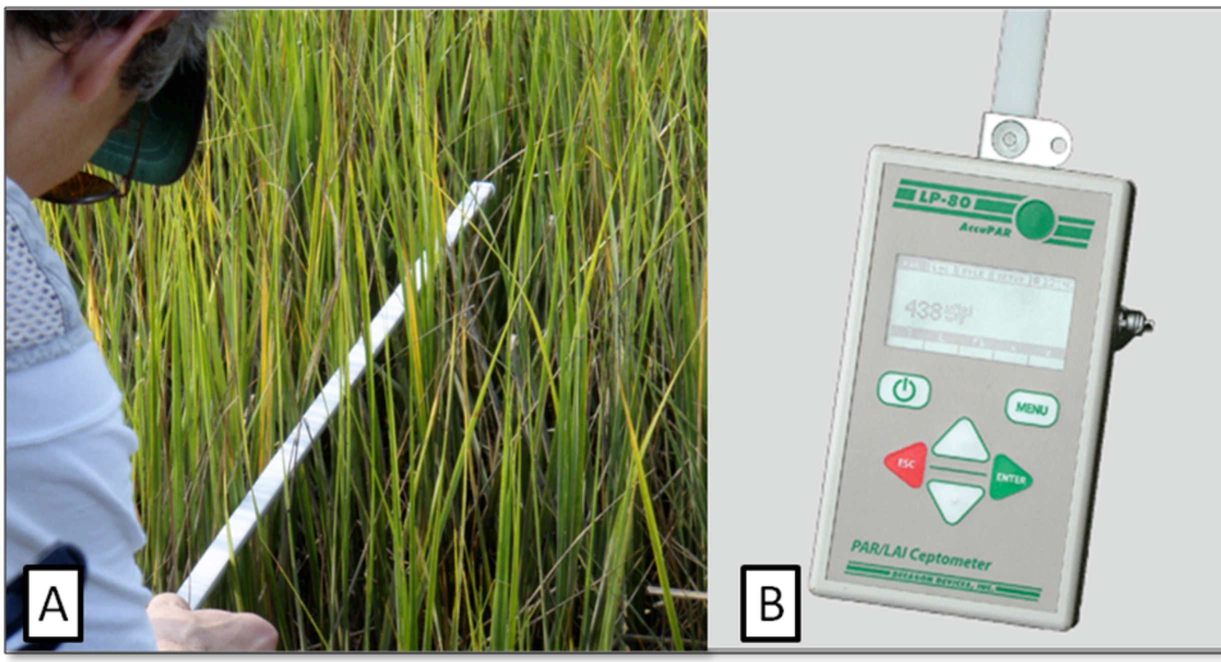

Figure 3.12. A ceptometer was used to measure PAR and LAI during the VCR'07 campaign. (A) Ceptometer being used to measure PAR. (B) AccuPAR LP-80.

3.10 Site Photographs. Photograph documentation is important to visually describe the site where data were collected. An Olympus® model U770SW/S770SW was used to capture greater than 1,600 photographs during the VCR'07 campaign. Photograph documentation included at the minimum, capturing the site's name (marked on orange flag) and the site's ground cover. Most sites have more than two pictures, with extra pictures of the groundcover and the site's situation. These photographs reside on the geodatabase drive at the file-path ..\VCR_GD\Attribute_Data\Photos_from_Field. All sites with spectra collected have their photograph contained in Appendix E.

4 Acknowledgments. The VCR'07 experiment and demonstration was a multidisciplinary and integrated effort. We appreciate the funding and technical contributions made by the NGA. The majority of scientists came from NRL's Remote Sensing Division and all in-water optic data were collected by scientists from NRL's Oceanography Division. Personnel from Marine Information Resources Corporation provided science support, which included a vessel and scientific divers. Additional support for fieldwork was garnered from NOAA's National Geodetic Survey, the University of Virginia, Purdue University, the U. S. Naval Academy, Old Dominion University, and The Nature Conservancy. This work would not have been possible without the special attention provided by motivated personnel from the ABCRC VCR/LTER Field Station.

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APPENDIX A

Web Resources

1. Introduction

There is considerable information relevant to VCR'07 and the exploitation of hyperspectral imagery stored on the World Wide Web. Therefore, the following list of Uniform Resource Locators (URLs) is provided since they complement this data report.

2. Web Resources

Aerosol Optical Depth, Earth Observatory, NASA, Available online. URL: http://earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MODAL2_M_AER_OD#, Accessed on September 22, 2007.

Global scale maps show average monthly aerosol amounts around the world based on observations from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite. Satellite measurements of aerosols, called *aerosol optical thickness,* are based on the fact that the particles change the way the atmosphere reflects and absorbs visible and infrared light. An optical thickness of less than 0.1 (palest yellow) indicates a crystal clear sky with maximum visibility, whereas a value of 1 (reddish brown) indicates very hazy conditions.

ITRES, Available online. URL: http://www.itres.com/CASI_1500, Accessed on August 17, 2007.

Company specializing in airborne hyperspectral sensor systems. ITRES offers six sensor products including the CASI 1500, the sensor used during the VCR.

Long-Term Ecological Research Network, LTER, Available online. URL: http://www.lternet.edu/sites/vcr/, Accessed on August 17, 2007.

The network is a collection of 26 ecological research sites conducting studies in five core research areas. The VCR is one of the research sites in the LTER network. The core research areas of the LTER network are as follows: (1) Pattern and control of primary production; (2) Spatial and temporal distribution of populations selected to represent trophic structure; (3) Pattern and control of organic matter accumulation in surface layers and sediments; (4) Patterns of inorganic inputs and movements of nutrients through soils, groundwater and surface waters; and (5) Patterns and frequency of site disturbances.

National Aeronautical and Space Administration-Wallops Island, VA, NASA, Available online. URL: http://www.nasa.gov/centers/wallops/about/index.html,

NASA has maintained a test facility located at Wallops Island since 1945 for the purpose of aeronautical research. The Wallops Island test facility is located at the northern end of the VCR and research efforts concerning the VCR have involved land classification and establishing training sites for remotely sensed imagery.

National Oceanic and Atmospheric Association, NOAA, Available online. URL: http://tidesandcurrents.noaa.gov/geo.shtml?location=8631044, Accessed on August 17, 2007.

NOAA has maintained a meterological and water level station at Wachapreague, VA (37° 36.4' N, 75° 41.2' W) since 1990. Water level data were used for validation of bathymetric products.

The Nature Conservancy, Available online. URL: http://www.nature.org/wherewework/northamerica/states/virginia/preserves/art15019.html, Accessed August 16, 2007.

The Nature Conservancy is a worldwide organization dedicated to protecting plants, animals and natural communities that represent the diversity of life on Earth. The group tries to maintain this diversity by working to protect various habitats. The VCR is one of the numerous places in Virginia that the Nature Conservancy is trying to protect. They have been instrumental in working with partners to preserve this habitat for over 30 years.

United States Fish and Wildlife Service, Available online. URL: http://www.fws.gov/northeast/va.htm, Accessed August 16, 2007.

Group involved with preservation of wildlife in the United States. They maintain a presence in the VCR by keeping wildlife refuges at Chincoteague Island, Wallops Island, Fisherman's Island, and on the Virginia Eastern Shore Mainland.

Virginia Places, Available online. URL: http://www.virginiaplaces.org/boundaries/gisdata.html, Accessed August 16, 2007.

A catalog of Virginia shapefiles, GIS data, and mapping information. Map resources can be used as additional information to GIS data included in the geodatabase.

William and Mary Institute of Marine Science, Available online. URL: http://web.vims.edu/bio/sav/, Accessed August 16, 2007.

A research institution specializing in the marine sciences especially focusing on SAVs. High resolution hyperspectral sensors can be used to detect a spectral response from coastal plants and SAVs. Water depth can also be inferred from SAVs.

APPENDIX B

Flight Lines

1. Introduction:

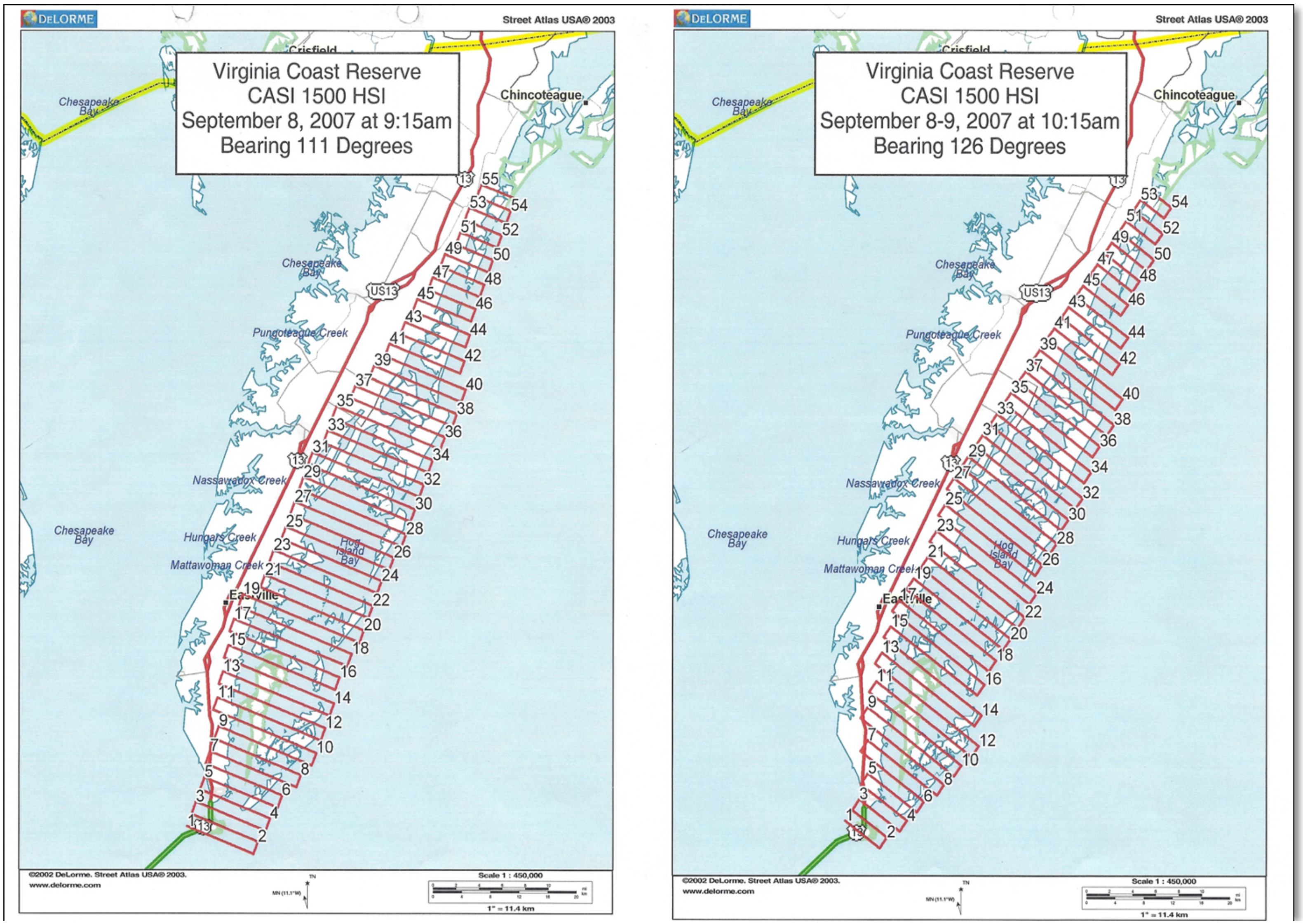
The Naval Research Laboratory mounted three remote sensing instruments in a De Havilland Canada DHC-6-200 Twin Otter: a CASI-1500 (see www.itres.com), which is a visible near infra-red (VNIR) hyperspectral camera operating in the 0.38-1.04 micron spectral range, a Surface Optics short-wave infra-red (SWIR) hyperspectral camera operating in the 0.9-1.7 micron range, and a single channel mid-wave infra-red (MWIR) camera operating in the 3-5 micron range. Airborne remote sensing coverage of the VCR study area by the three cameras occurred during the period from September 7-21, 2007.

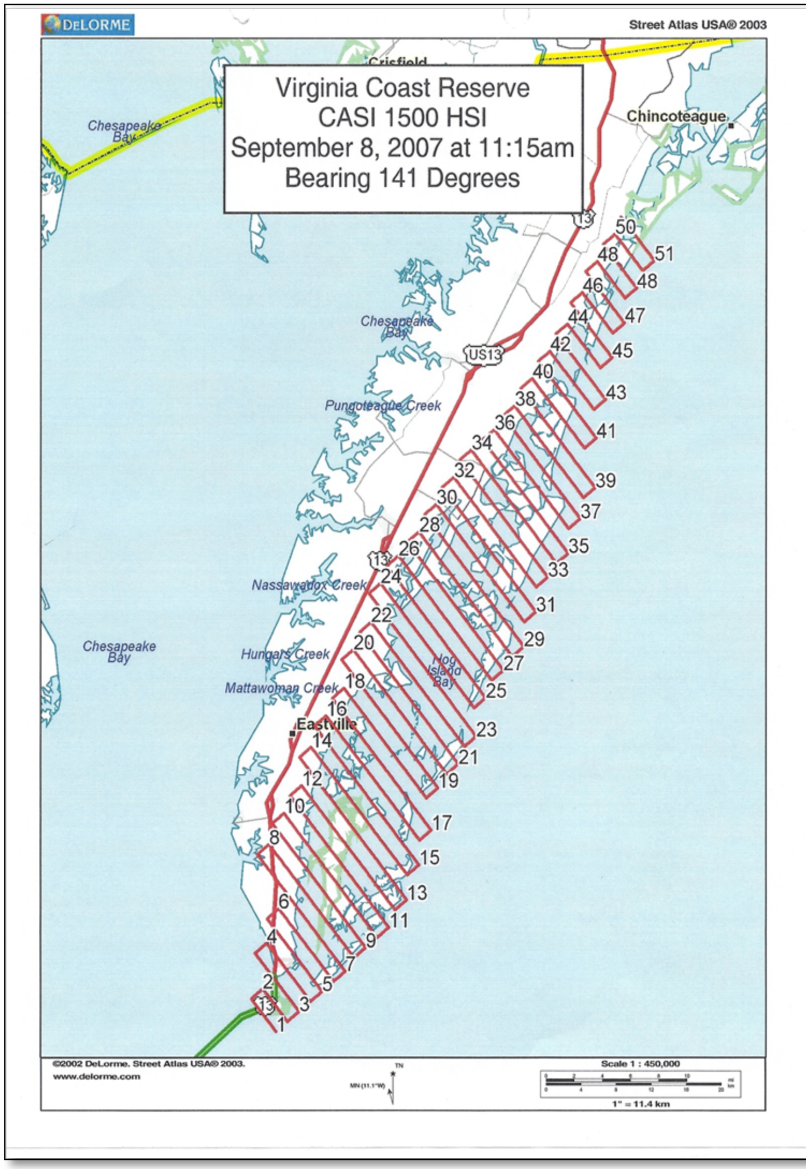
Flight lines were planned to minimize the effects of glint over the water and marsh systems by computing optimal times of day for data acquisition, and to maintain flight line trajectories into and out of the sun. This has the benefit of minimizing glint (if time of day is chosen correctly) and of maintaining uniform illumination across the sensor array. In order to maintain a heading into and out of the sun, flight line azimuthal bearing was defined for each hour in the air because the solar azimuth changes rapidly at the VCR during the study period. At the beginning of September, the optimal times for HSI data collection are typically in 2-2.5 hour windows in the morning and afternoon, while at the third week in September the optimal data collection times occurred in a much broader single window extending from 9:30-16:30.

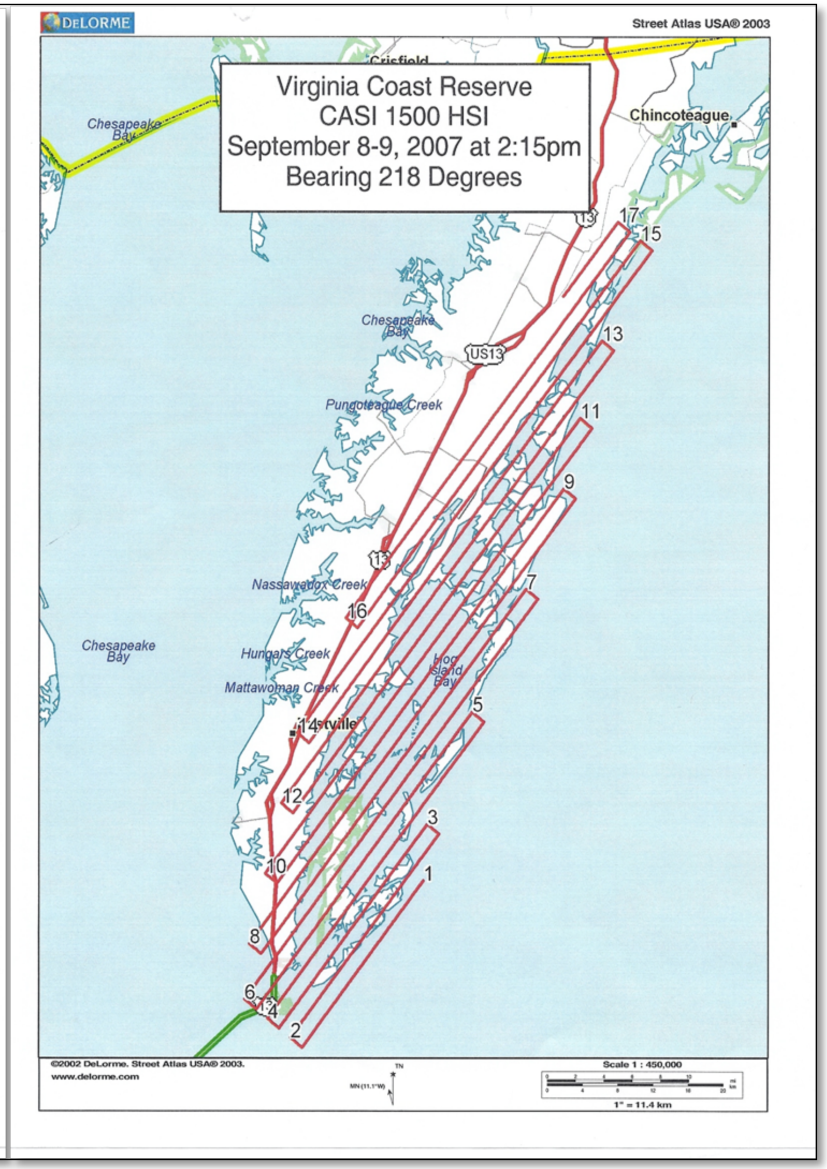
The typical altitude for most flights was 3000m, and the corresponding ground sampled distance (spatial resolution) was 1.5m. At this altitude, the 1500 cross-track pixels of our CASI-1500 hyperspectral camera achieved a swath width of 2.25km. Note that at this altitude, the spatial resolution of our Surface Optics SWIR hyperspectral camera was about 2.3m with a swath width of about 1.5km. The thermal camera was more limited, with a GSD of typically 3-4m and a swath width of about 0.75km.

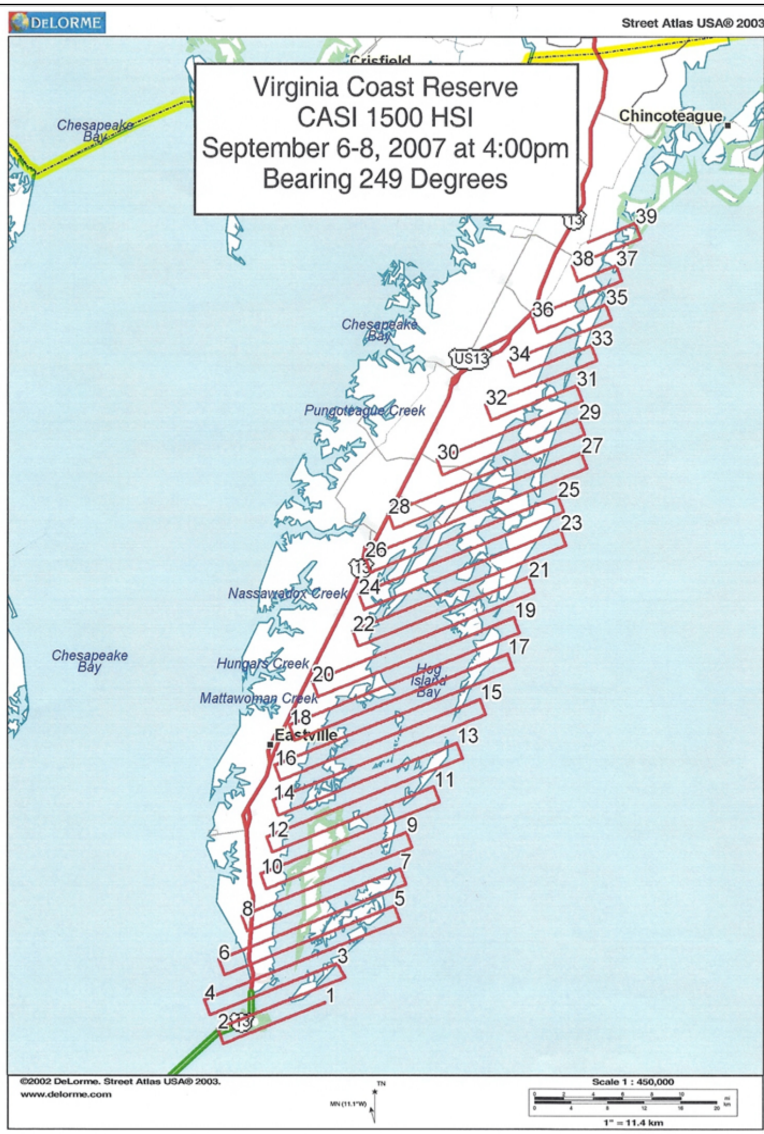
The following pages display flight paths for the CASI 1500 HSI sensor and the SWIR HSI sensor. Each of the figures contains the same azimuthal bearing but the SWIR sensor contains flight lines with a narrower swath width.

2. CASI 1500 HSI Flight Lines




DeLORME
Street Atlas USA® 2003
Virginia Coast Reserve
CASI 1500 HSI
September 8, 2007 at 11:15am
Bearing 141 Degrees
Crisfield
Chincoteague
Chesapeake Bay
Pungoteague Creek
Nassawadox Creek
Hungars Creek
Mattawoman Creek
Eastville
Hog Island Bay
©2002 DeLorme. Street Atlas USA® 2003.
www.delorme.com
Scale 1 : 450,000
1" = 11.4 km


DeLORME
Street Atlas USA® 2003
Virginia Coast Reserve
CASI 1500 HSI
September 8-9, 2007 at 2:15pm
Bearing 218 Degrees
Crisfield
Chincoteague
Chesapeake Bay
Pungoteague Creek
Nassawadox Creek
Hungars Creek
Mattawoman Creek
Hog Island Bay
©2002 DeLorme. Street Atlas USA® 2003.
www.delorme.com
Scale 1 : 450,000
1" = 11.4 km



DeLorme
Street Atlas USA® 2003
Virginia Coast Reserve
CASI 1500 HSI
September 6-8, 2007 at 4:00pm
Bearing 249 Degrees
Crisfield
Chincoteague
Chesapeake Bay
Pungoteague Creek
Nassawadox Creek
Hungars Creek
Mattawoman Creek
Eastville
Hog Island Bay
©2002 DeLorme. Street Atlas USA® 2003.
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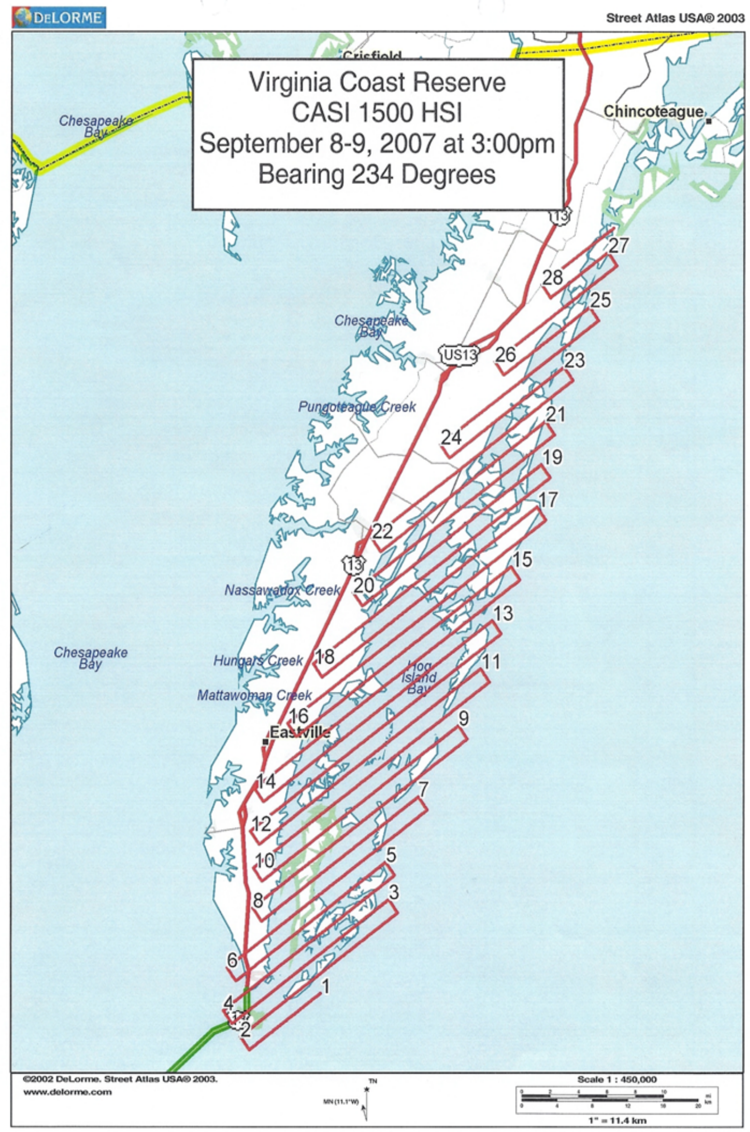
Scale 1 : 450,000
1" = 11.4 km



DeLorme
Street Atlas USA® 2003
Virginia Coast Reserve
CASI 1500 HSI
September 8-9, 2007 at 3:00pm
Bearing 234 Degrees
Crisfield
Chincoteague
Chesapeake Bay
Pungoteague Creek
Nassawadox Creek
Hungars Creek
Mattawoman Creek
Eastville
Hog Island Bay
©2002 DeLorme. Street Atlas USA® 2003.
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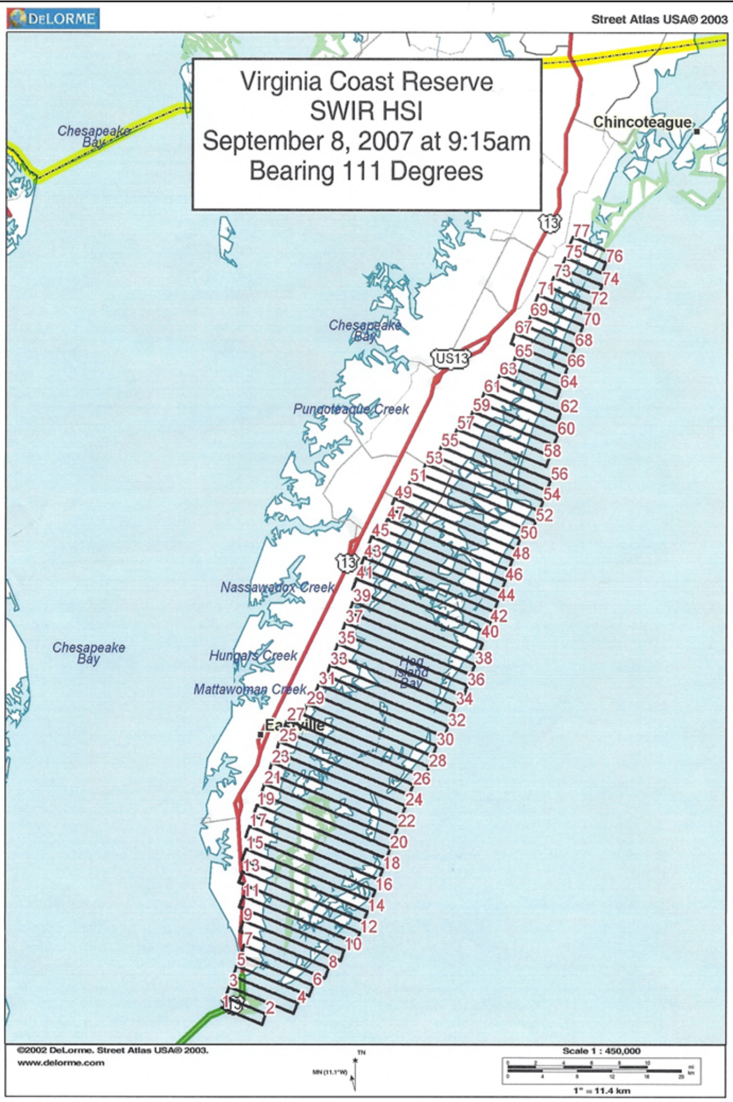
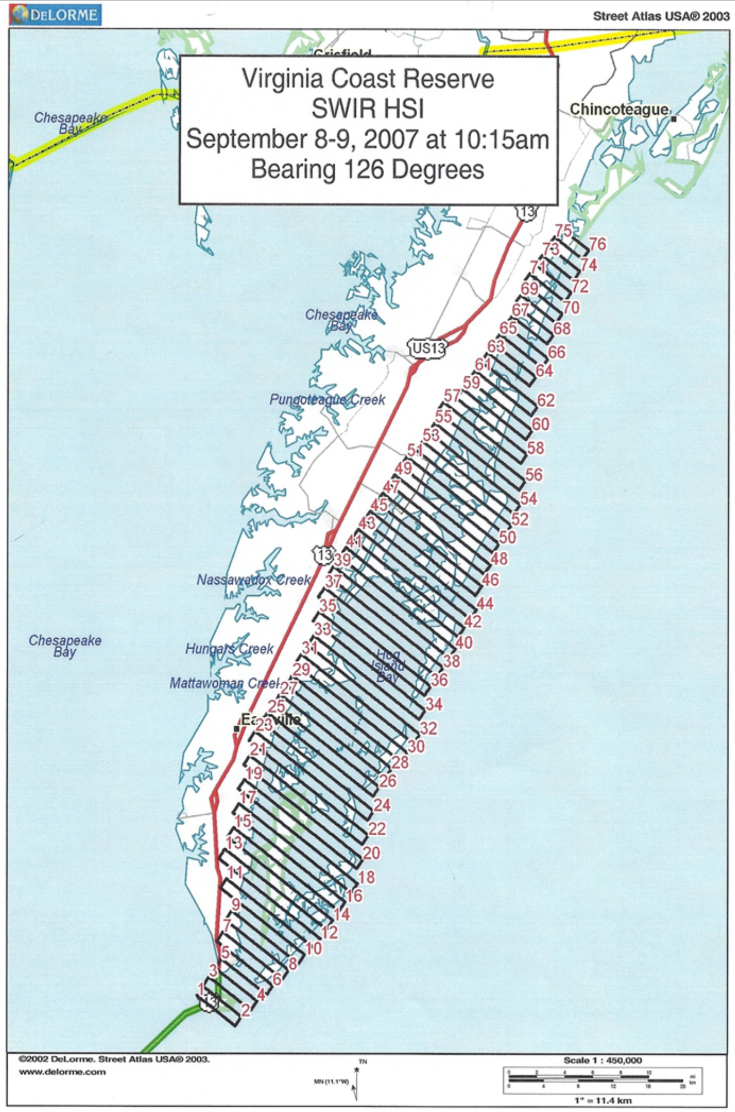
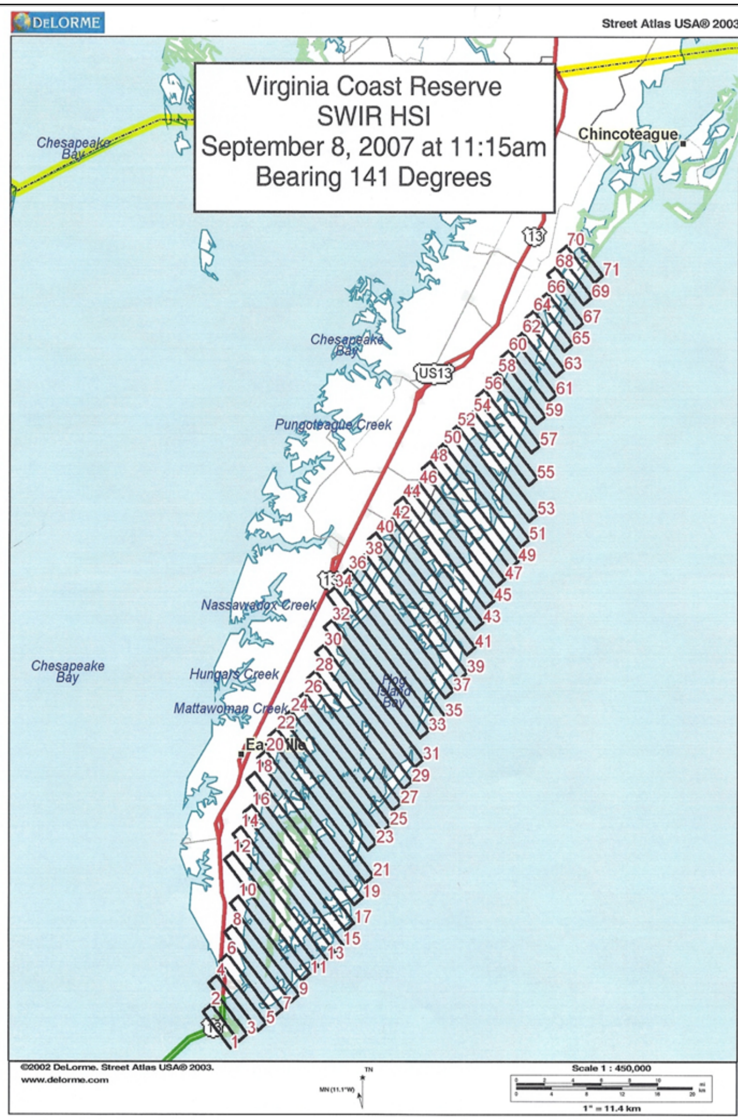
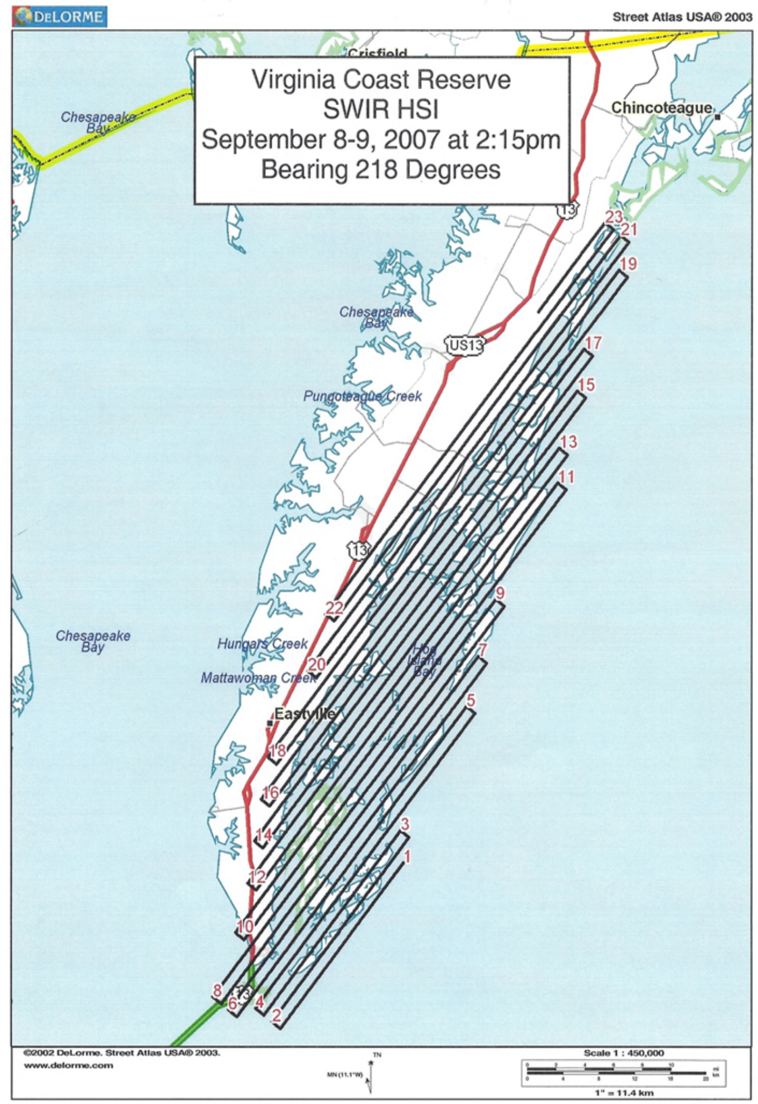
Scale 1 : 450,000
1" = 11.4 km

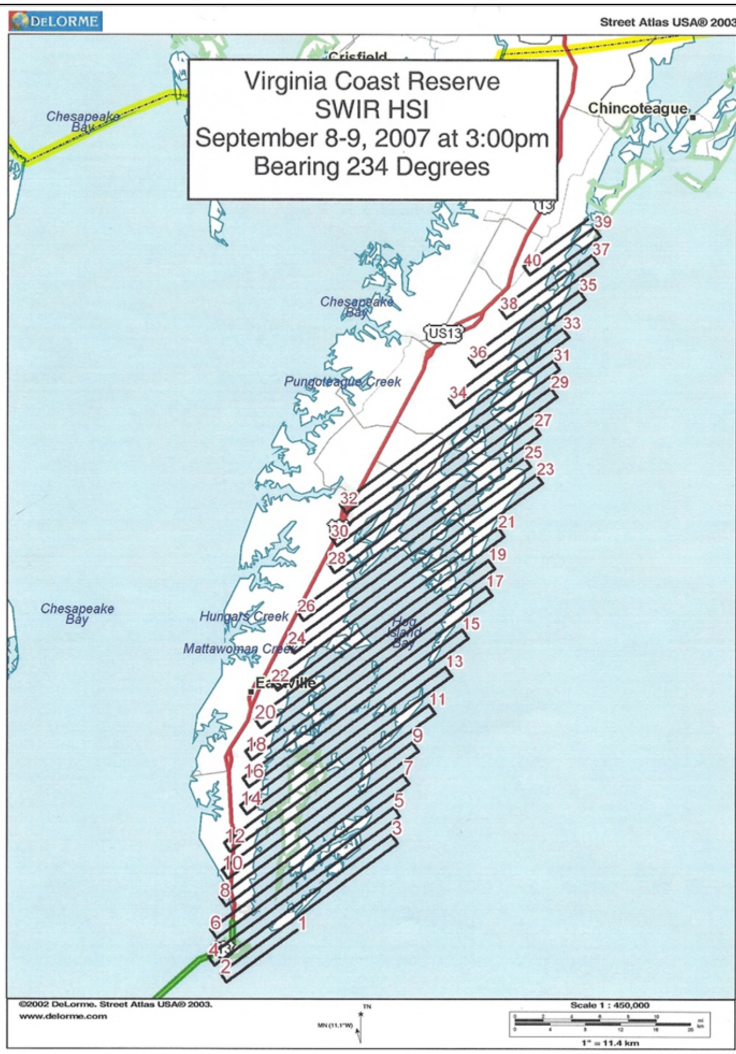
3. SWIR HSI Flight Lines

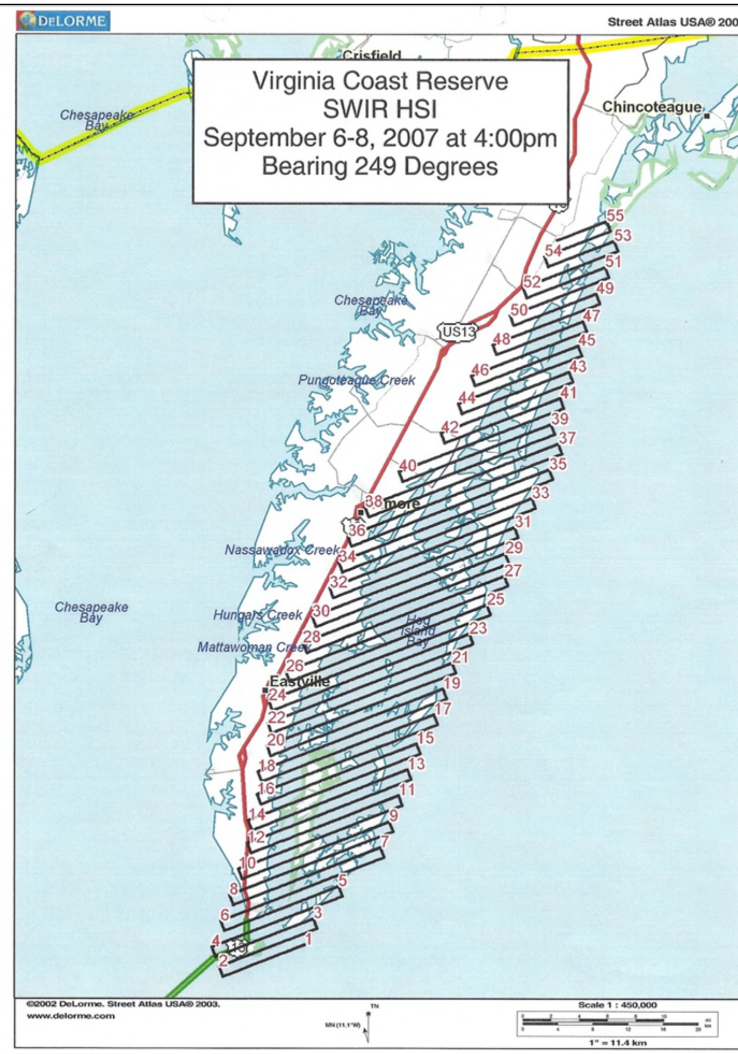





DeLorme
Street Atlas USA® 2003
Virginia Coast Reserve
SWIR HSI
September 8, 2007 at 11:15am
Bearing 141 Degrees
Chincoteague
Chesapeake Bay
Pungoteague Creek
Nassawadox Creek
Hungars Creek
Mattawoman Creek
Eastville
Hog Island Bay
©2002 DeLorme. Street Atlas USA® 2003.
www.delorme.com
Scale 1 : 450,000
1" = 11.4 km


DeLorme
Street Atlas USA® 2003
Virginia Coast Reserve
SWIR HSI
September 8-9, 2007 at 2:15pm
Bearing 218 Degrees
Crisfield
Chincoteague
Chesapeake Bay
Pungoteague Creek
Hungars Creek
Mattawoman Creek
Eastville
Hog Island Bay
©2002 DeLorme. Street Atlas USA® 2003.
www.delorme.com
Scale 1 : 450,000
1" = 11.4 km


DELORME
Street Atlas USA® 2003
Virginia Coast Reserve
SWIR HSI
September 8-9, 2007 at 3:00pm
Bearing 234 Degrees
Crisfield
Chincoteague
Chesapeake Bay
Pungoteague Creek
Hungars Creek
Mattawoman Creek
Eastville
Hog Island Bay
US13
©2002 DeLorme. Street Atlas USA® 2003.
www.delorme.com
Scale 1 : 450,000
1" = 11.4 km


DELORME
Street Atlas USA® 2003
Virginia Coast Reserve
SWIR HSI
September 6-8, 2007 at 4:00pm
Bearing 249 Degrees
Crisfield
Chincoteague
Chesapeake Bay
Pungoteague Creek
Nassawadox Creek
Hungars Creek
Mattawoman Creek
Eastville
Hog Island Bay
US13
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www.delorme.com
Scale 1 : 450,000
1" = 11.4 km

APPENDIX C

Quicklook Imagery

1. Introduction

Imagery quicklooks are georectified images that show the extent of the HSI taken during the VCR'07 campaign. Programs such as ArcMap and ArcGIS Explorer cannot fully utilize the capabilities of HSI like ENVI can, so quicklook images are developed for quick viewing of the flight line's position, image quality, and the presence of clouds. The quicklook images are RGB images which are displayed as JPEG or TIFF format.

For the majority of the data collections, the sensor was flown into and out of the sun to ensure uniform illumination across the sensor array and to minimize glint. Times of day were chosen to further minimize glint (solar zenith angle between 35-55 degrees in most instances) from water surfaces and also to capture the study area at different tidal stages. Water level information was obtained in the form of NOAA tide predictions and real time water level fluctuations from local gauges. Tidal information can be seen in Appendix D.

2. Quicklook Image Location Matrix

Abbreviations used in Table C-2 are seen in Table C -1.Table C-2 below presents the names of the CASI quicklook images available in the geodatabase. The abbreviated names of islands and locations appear in the top row of the table. If the island/location appears in an image it is marked with **Y** and if the island/location does not appear in an image, it is marked with an X. If the flight line contained a worksite, it is marked with a **Y** with the location(s) of where the site is located written after the **Y**. The comments section briefly describes the positioning of the flight line.

Table C -1

ABBREVIATION	NAME	ABBREVIATION	NAME
B	Boxwood	P	Parramore Island
CT	Chincoteague Island	S	Smith Island
C	Cobb's Island	SL	Steelman's Landing
CL	Cushman's Landing	UPC	Upper Phillip's Creek
GC	Gator Creek	W	Wreck Island
H	Hog Island	X	Not present in image
IT	Indiantown	**Y**	Present in image

Table C-2

Flight path name	Date	B	CT	C	CL	GC	H	IT	P	S	SL	UPC	W	Worksites	Comments
CASI_2007_09_07_ 124233	7-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal Lands West of Cobb, Wreck and Hog
CASI_2007_09_07_ 125046	7-Sep	X	X	**Y**	X	X	**Y**	X	X	X	X	X	X	X	North Cobb, South Hog Island
CASI_2007_09_07_ 125917	7-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	**Y**	**Y**; W	Mockhorn Island, South Hog, North Wreck
CASI_2007_09_07_ 130810	7-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	**Y**; H	Hog Island, west of Cobb's Island
CASI_2007_09_07_ 131727	7-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	**Y**; H	Hog Island, west of Cobb's Island
CASI_2007_09_07_ 132602	7-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	**Y**; H	Hog Island, west of Cobb's Island
CASI_2007_09_07_ 133636	7-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal lands west of Cobb's, Hog Islands
CASI_2007_09_07_ 134512	7-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal lands west of Cobb's, Hog Islands
CASI_2007_09_07_ 135536	7-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal lands west of Cobb's, Hog Islands
CASI_2007_09_07_ 140657	7-Sep	**Y**	X	X	X	X	X	X	X	X	X	X	X	**Y**: B	Mainland; Boxwood area
CASI_2007_09_07_ 141745	7-Sep	X	X	X	X	X	X	X	X	X	X	**Y**	X	**Y**: UPC	Upper Phillips Creek mainland and Tidal lands south
CASI_2007_09_07_ 142836	7-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Mainland north of UPC to tidal lands south and east of UPC
CASI_2007_09_07_ 143922	7-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Mainland north of UPC to tidal lands south and east of UPC
CASI_2007_09_07_ 145336	7-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Mainland north of UPC to tidal lands south and east of UPC
CASI_2007_09_07_ 151512	7-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	Tidal lands west of Cobb's, Hog Islands
CASI_2007_09_07_ 152316	7-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	X	X	Tidal lands west of Cobb's, Wreck Islands
CASI_2007_09_07_ 153054	7-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	**Y**	**Y**; W	North Wreck Island and South Cobb's Island
CASI_2007_09_08_ 143418	8-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal lands west of Hog, Cobb's, Wreck Island
CASI_2007_09_08_ 144013	8-Sep	X	X	X	**Y**	X	X	X	X	X	**Y**	X	X	**Y**:CL, SL	Mainland-South west of CL, SL, to North east tidal lands

CASI_2007_09_08_ 144743	8-Sep	X	X	X	**Y**	**Y**	X	X	X	X	**Y**	X	X	**Y**: GC, SL, CL	Mainland-South west of GC,CL, SL, to North east tidal lands
CASI_2007_09_08_ 145510	8-Sep	X	X	X	X	**Y**	X	X	X	X	X	X	X	**Y**: partial GC	Mainland-South of GC to tidal lands Northeast
CASI_2007_09_08_ 150331	8-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal lands west of Smith and Wreck Islands
CASI_2007_09_08_ 151129	8-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal lands west of Smith and Wreck Islands
CASI_2007_09_08_ 151942	8-Sep	X	X	X	X	X	X	X	X	**Y**	X	X	X	**Y**; North and South SI	Smith Island and Godwin's Island
CASI_2007_09_08_ 152825	8-Sep	X	X	X	X	X	X	X	X	**Y**	X	X	X	**Y**: North S	Smith Island
CASI_2007_09_08_ 155127	8-Sep	X	X	X	X	X	X	X	X	X	X	X	**Y**	X	South of Wreck Island to East of Wreck Island
CASI_2007_09_08_ 155946	8-Sep	X	X	X	X	X	X	X	X	X	X	X	**Y**	X	Middle Wreck Island
CASI_2007_09_08_ 160808	8-Sep	X	X	X	X	X	X	X	X	X	X	X	**Y**	**Y**; W	North Wreck Island
CASI_2007_09_08_ 161627	8-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	**Y**	**Y**; W	North Wreck Island and South Cobb's Island
CASI_2007_09_08_ 162538	8-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	X	X	South Cobb's Island and tidal lands south west
CASI_2007_09_08_ 163429	8-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	X	X	Middle Cobb's Island and tidal lands south west
CASI_2007_09_08_ 164307	8-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	X	X	North Cobb's Island and tidal lands south west
CASI_2007_09_08_ 165143	8-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	South Wreck Islands and tidal lands south west
CASI_2007_09_10_ 93203	10-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	Middle Hog Island and tidal lands north west
CASI_2007_09_10_ 94118	10-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	Middle Parramore Island and offshore regions southeast
CASI_2007_09_10_ 94420	10-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Mainland and tidal lands west of Parramore Island
CASI_2007_09_10_ 95054	10-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	Middle Parramore Island; Tidal lands west and offshore regions
CASI_2007_09_10_ 95912	10-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	South Parramore Island; Tidal lands west and offshore regions southeast
CASI_2007_09_10_ 100938	10-Sep	X	X	X	X	X	**Y**	X	**Y**	X	X	X	X	X	South Parramore Island and North Hog Island and tidal lands west
CASI_2007_09_10_ 101754	10-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	**Y**; H	North Hog Island and tidal lands northwest

CASI_2007_09_12_ 91653	12-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	North Parramore Island and tidal lands west
CASI_2007_09_12_ 93003	12-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	**Y**; P	North Parramore Island and tidal lands west
CASI_2007_09_12_ 93617	12-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	**Y**; P	North Parramore Island and tidal lands west
CASI_2007_09_12_ 94452	12-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	Middle Parramore Island and tidal lands west
CASI_2007_09_12_ 95125	12-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	Middle Parramore Island and tidal lands west
CASI_2007_09_12_ 95920	12-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	Middle Parramore Island and tidal lands west
CASI_2007_09_12_ 100608	12-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	South Parramore Island and tidal lands west
CASI_2007_09_12_ 101440	12-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	Middle Parramore Island and tidal lands west
CASI_2007_09_12_ 102910	12-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	South Parramore Island and tidal lands west
CASI_2007_09_12_ 103536	12-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	South Parramore Island and tidal lands west
CASI_2007_09_12_ 104328	12-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	North Hog Island and tidal lands northwest
CASI_2007_09_12_ 105055	12-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	North Hog Island and tidal lands northwest
CASI_2007_09_12_ 105839	12-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	**Y**; H	North Hog Island and tidal lands northwest
CASI_2007_09_12_ 110656	12-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	Middle Hog Island and tidal lands northwest
CASI_2007_09_12_ 111528	12-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	Middle Hog Island and tidal lands northwest
CASI_2007_09_12_ 112438	12-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	Middle Hog Island and tidal lands northwest
CASI_2007_09_12_ 113257	12-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	Middle Hog Island and tidal lands northwest
CASI_2007_09_12_ 114104	12-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	Middle Hog Island and tidal lands northwest
CASI_2007_09_12_ 121005	12-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	South Hog Island and tidal lands northwest
CASI_2007_09_12_ 121906	12-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	X	X	North Cobb's Island and tidal lands northwest
CASI_2007_09_12_ 152043	12-Sep	X	**Y**	X	X	X	X	X	X	X	X	X	X	X	Chinoteague Island and tidal lands southwest

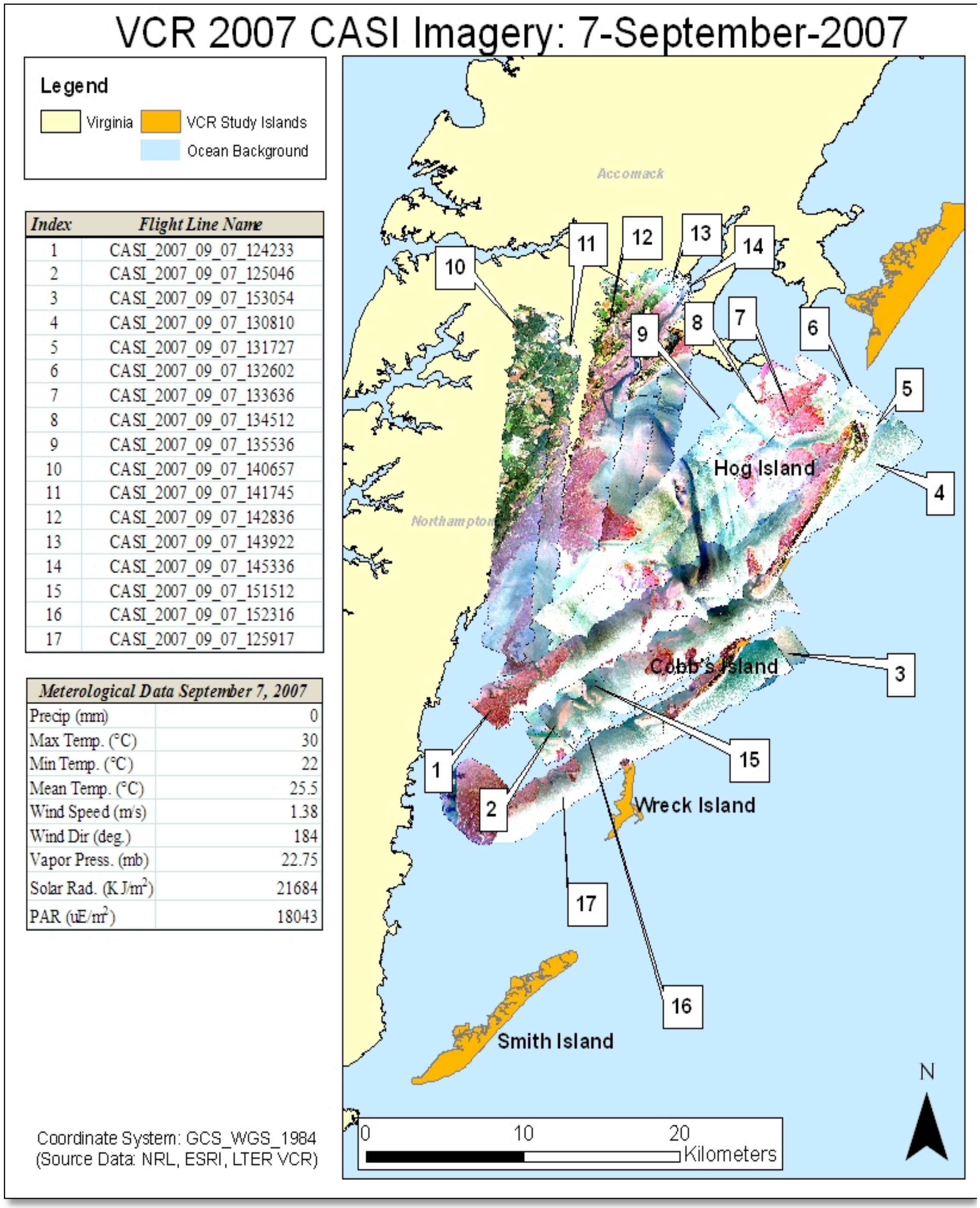
CASI_2007_09_12_ 153227	12-Sep	X	**Y**	X	X	X	X	X	X	X	X	X	X	X	Chinoteague Island and tidal lands southwest
CASI_2007_09_12_ 154918	12-Sep	X	**Y**	X	X	X	X	X	X	X	X	X	X	X	North VA Assateague Island and tidal lands west
CASI_2007_09_12_ 160500	12-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal lands west of Assateague Island
CASI_2007_09_12_ 161627	12-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal lands north and west of VA portion of Assateauge Island
CASI_2007_09_12_ 163015	12-Sep	X	**Y**	X	X	X	X	X	X	X	X	X	X	X	Tidal lands/mainland west of Chincoteague Island
CASI_2007_09_12_ 164212	12-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Bay west of MD Assateague Island
CASI_2007_09_12_ 165538	12-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Wallops Island test facility
CASI_2007_09_13_ 93136	13-Sep	X	X	X	X	X	X	X	X	X	X	X	**Y**	X	South Wreck Island and tidal lands west
CASI_2007_09_13_ 93728	13-Sep	X	X	X	X	X	X	X	X	X	X	X	**Y**	X	South Wreck Island and tidal lands west
CASI_2007_09_13_ 94527	13-Sep	X	X	X	X	X	X	X	X	X	X	X	**Y**	**Y**; W	North Wreck Island and tidal lands northwest
CASI_2007_09_13_ 95916	13-Sep	X	X	**Y**	X	X	X	**Y**	X	X	X	X	X	**Y**; IT	Indiantown to South Cobb's Island and tidal lands between
CASI_2007_09_13_ 101310	13-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	X	X	South Cobb's Island and tidal lands west
CASI_2007_09_13_ 103026	13-Sep	**Y**	X	**Y**	X	X	X	X	X	X	X	X	X	**Y**; B	Boxood to South Cobb's Island
CASI_2007_09_13_ 103713	13-Sep	**Y**	X	**Y**	X	X	X	X	X	X	X	X	X	**Y**; B	Boxood to South Cobb's Island
CASI_2007_09_13_ 104545	13-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	X	X	North of Boxood to South Cobb's Island
CASI_2007_09_13_ 105151	13-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	X	X	North of Boxood to Middle Cobb's Island
CASI_2007_09_13_ 105945	13-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	X	X	North of Boxood to North Cobb's Island
CASI_2007_09_13_ 110638	13-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	X	X	North of Boxood to North Cobb's Island
CASI_2007_09_13_ 111658	13-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	North of UPC to South Hog Island
CASI_2007_09_13_ 112459	13-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	North of UPC to South Hog Island
CASI_2007_09_13_ 113313	13-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	North of UPC to South Hog Island

CASI_2007_09_13_ 114024	13-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	North of UPC to Middle Hog Island
CASI_2007_09_13_ 114816	13-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	Middle Hog Island and tidal lands northwest
CASI_2007_09_13_ 115501	13-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	Middle Hog Island and tidal lands northwest
CASI_2007_09_13_ 120247	13-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	**Y**; H	North Hog Island and tidal lands northwest
CASI_2007_09_13_ 120947	13-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	**Y**; H	North Hog Island and tidal lands northwest
CASI_2007_09_13_ 140645	13-Sep	X	**Y**	X	X	X	X	X	X	X	X	X	X	X	Metompkin Island Chincoteague Islands National Seashore
CASI_2007_09_13_ 141459	13-Sep	X	**Y**	X	X	X	X	X	X	X	X	X	X	X	Metompkin Island Chincoteague Islands National Seashore
CASI_2007_09_13_ 142451	13-Sep	X	**Y**	X	X	X	X	X	X	X	X	X	X	X	Southern Portion Chincoteague Islands National Seashore
CASI_2007_09_13_ 143121	13-Sep	X	**Y**	X	X	X	X	X	X	X	X	X	X	X	Southern Portion Chincoteague Islands National Seashore
CASI_2007_09_13_ 144106	13-Sep	X	**Y**	X	X	X	X	X	X	X	X	X	X	X	Southern Portion Chincoteague Islands National Seashore
CASI_2007_09_13_ 145743	13-Sep	X	X	X	X	X	X	X	X	**Y**	X	X	**Y**	**Y**; South S, W	Wreck and Smith Islands
CASI_2007_09_13_ 150714	13-Sep	X	X	X	X	X	X	X	X	**Y**	X	X	**Y**	**Y**; South S, W	Wreck and Smith Islands
CASI_2007_09_13_ 151650	13-Sep	X	X	X	X	X	X	X	X	**Y**	X	X	**Y**	**Y**; South S	Wreck and Smith Islands
CASI_2007_09_13_ 152604	13-Sep	X	X	X	X	X	X	X	X	**Y**	X	X	X	**Y**; North S	Smith Island
CASI_2007_09_13_ 153532	13-Sep	X	X	X	X	X	X	X	X	**Y**	X	X	X	**Y**; North S	Smith Island
CASI_2007_09_16_ 91937	16-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	**Y**; H	Hog Island, tidal lands west
CASI_2007_09_16_ 92658	16-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	**Y**; H	Hog Island, tidal lands west
CASI_2007_09_16_ 93558	16-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	Hog Island, tidal lands west
CASI_2007_09_16_ 94334	16-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	Hog Island, tidal lands west
CASI_2007_09_16_ 95307	16-Sep	X	X	X	X	X	**Y**	X	X	X	X	**Y**	X	**Y**; UPC	Middle Hog Island, tidal lands west to UPC
CASI_2007_09_16_ 100102	16-Sep	X	X	X	X	X	**Y**	X	X	X	X	**Y**	X	**Y**; UPC	Middle Hog Island, tidal lands west to UPC

CASI_2007_09_16_ 101018	16-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	Middle Hog Island, tidal lands west to south of UPC
CASI_2007_09_16_ 102111	16-Sep	X	X	X	X	X	**Y**	X	X	X	X	X	X	X	Middle Hog Island, tidal lands west to south of UPC
CASI_2007_09_16_ 103537	16-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	Southern Parramore Island and tidal lands to west
CASI_2007_09_16_ 104355	16-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	Southern Parramore Island and tidal lands to west
CASI_2007_09_16_ 105218	16-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	Southern Parramore Island and tidal lands to west
CASI_2007_09_16_ 105958	16-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	Middle Parramore Island and tidal lands to west
CASI_2007_09_16_ 110800	16-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	Middle Parramore Island and tidal lands to west
CASI_2007_09_16_ 111420	16-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	**Y**; P	North Parramore Island and tidal lands to west
CASI_2007_09_16_ 112132	16-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	North Parramore Island and tidal lands to west
CASI_2007_09_16_ 112723	16-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	North Parramore Island and tidal lands to west
CASI_2007_09_16_ 114404	16-Sep	X	**Y**	X	X	X	X	X	X	X	X	X	X	X	Southern portion of Chincoteague Island National Seashore; East of Wallops Island
CASI_2007_09_16_ 115220	16-Sep	X	**Y**	X	X	X	X	X	X	X	X	X	X	X	Southern portion of Chincoteague Island National Seashore; East of Wallops Island
CASI_2007_09_16_ 115916	16-Sep	X	**Y**	X	X	X	X	X	X	X	X	X	X	X	Southern portion of Chincoteague Island National Seashore; East of Wallops Island
CASI_2007_09_16_ 120748	16-Sep	X	**Y**	X	X	X	X	X	X	X	X	X	X	X	Southern portion of Chincoteague Island National Seashore; East of Wallops Island
CASI_2007_09_16_ 123815	16-Sep	X	**Y**	X	X	X	X	X	X	X	X	X	X	X	Southern portion of Chincoteague Island National Seashore; East of Wallops Island
CASI_2007_09_17_ 145235	17-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal lands northwest of Parramore Island
CASI_2007_09_17_ 145758	17-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal lands northwest of Parramore Island
CASI_2007_09_17_ 150326	17-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal lands northwest of Parramore Island
CASI_2007_09_17_ 151005	17-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal lands northwest of Parramore Island
CASI_2007_09_17_ 151600	17-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	X	Tidal lands northwest of Parramore Island; Northwest tip of Parramore Island
CASI_2007_09_17_ 152300	17-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	**Y**; P	Tidal lands west of Parramore Island; Northwest portion of Parramore Island

CASI_2007_09_17_ 153004	17-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	**Y**; P	Tidal lands west of Parramore Island; Northwest portion of Parramore Island
CASI_2007_09_17_ 154011	17-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	X	X	Cobb's Island and Mockhorn Island; Tidal lands southwest of Cobb's Island
CASI_2007_09_17_ 154943	17-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	X	X	Cobb's Island; Tidal lands southwest of Cobb's Island
CASI_2007_09_17_ 160213	17-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal lands northwest of Parramore Island
CASI_2007_09_17_ 160738	17-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal lands northwest of Parramore Island
CASI_2007_09_17_ 161640	17-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal lands northwest of Parramore Island
CASI_2007_09_17_ 162332	17-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal lands northwest of Parramore Island
CASI_2007_09_17_ 163141	17-Sep	X	X	X	X	X	X	X	**Y**	X	X	X	X	**Y**: partial P	Tidal lands west of Parramore Island
CASI_2007_09_17_ 164153	17-Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	Tidal lands northwest of Parramore Island
CASI_2007_09_17_ 165508	17-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	X	X	Cobb's Island and tidal lands to the southwest
CASI_2007_09_17_ 170210	17-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	X	X	Cobb's Island and tidal lands to the southwest
CASI_2007_09_17_ 170925	17-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	X	X	Cobb's Island and tidal lands to the southwest
CASI_2007_09_17_ 172451	17-Sep	X	X	**Y**	X	X	X	X	X	X	X	X	X	X	Cobb's Island and tidal lands to the southwest

3. Quicklook Imagery Views



VCR 2007 CASI Imagery: 8-September-2007

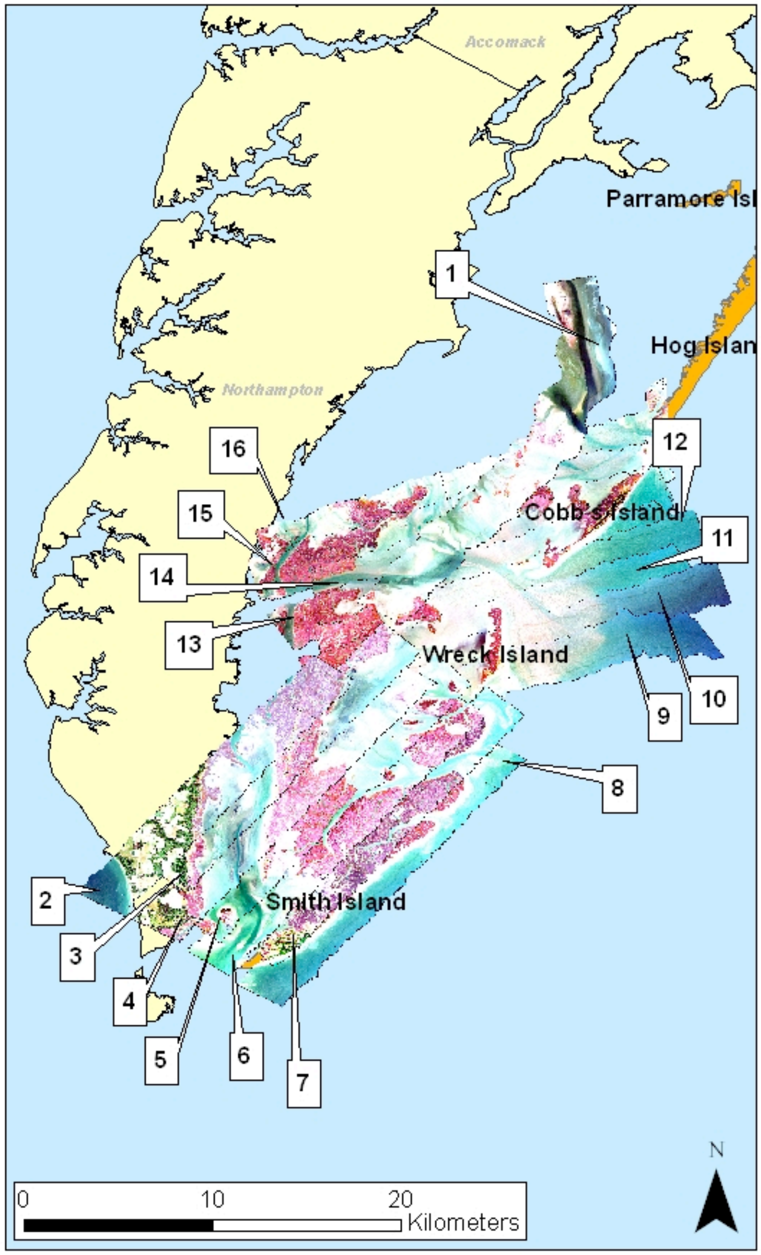
Legend

- Virginia
- VCR Study Islands
- Ocean Background

Index	Flight Line Name
1	CASI_2007_09_08_143418
2	CASI_2007_09_08_144013
3	CASI_2007_09_08_144743
4	CASI_2007_09_08_145510
5	CASI_2007_09_08_150331
6	CASI_2007_09_08_151129
7	CASI_2007_09_08_151942
8	CASI_2007_09_08_152825
9	CASI_2007_09_08_155127
10	CASI_2007_09_08_155946
11	CASI_2007_09_08_160808
12	CASI_2007_09_08_161627
13	CASI_2007_09_08_162538
14	CASI_2007_09_08_163429
15	CASI_2007_09_08_164307
16	CASI_2007_09_08_165143

Meterological Data September 8, 2007	
Precip (mm)	0
Max Temp. (°C)	30
Min Temp. (°C)	19
Mean Temp. (°C)	24.9
Wind Speed (m/s)	1.04
Wind Dir (deg.)	200
Vapor Press. (mb)	21.03
Solar Rad. (KJ/m^2)	24005
PAR (uE/m^2)	9416

Coordinate System: GCS_WGS_1984
(Source Data: NRL, ESRI, LTER)



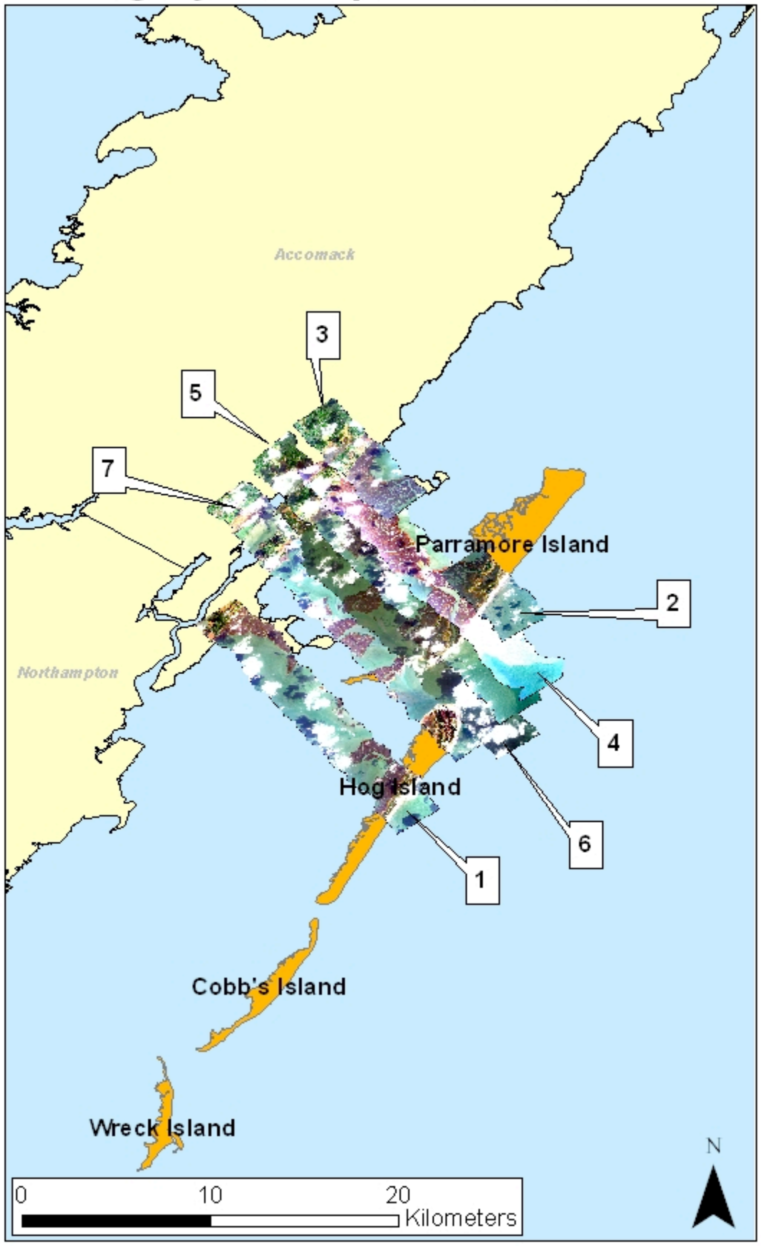
VCR 2007 CASI Imagery: 10-September-2007

Legend

Virginia | VCR Study Islands | Ocean Background

Index	*Flight Line Name*
1	CASI_2007_09_10_093203
2	CASI_2007_09_10_094118
3	CASI_2007_09_10_094420
4	CASI_2007_09_10_095054
5	CASI_2007_09_10_095912
6	CASI_2007_09_10_100938
7	CASI_2007_09_10_101754

Meterological Data September 10, 2007	
Precip (mm)	0
Max Temp. (°C)	33
Min Temp. (°C)	23
Mean Temp. (°C)	27.2
Wind Speed (m/s)	1.41
Wind Dir (deg.)	71
Vapor Press. (mb)	26.95
Solar Rad. (KJ/m^2)	18790
PAR (uE/m^2)	14174



Coordinate System: GCS_WGS_1984
(Source Data: NRL, ESRI, LTER)

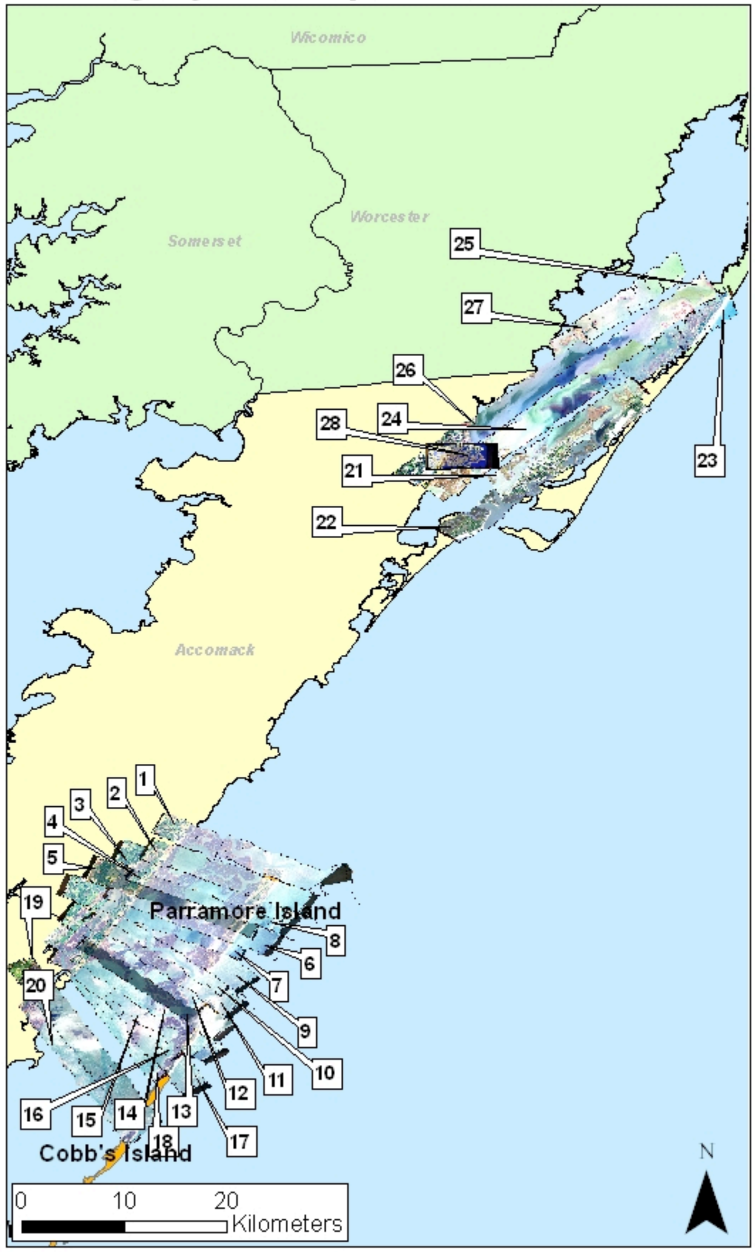
VCR 2007 CASI Imagery: 12-September-2007

Legend

State Name
- Maryland
- Virginia
- VCR Study Islands
- Ocean Background

Index	Flight Line Name
1	CASI_2007_09_12_091653
2	CASI_2007_09_12_093003
3	CASI_2007_09_12_093617
4	CASI_2007_09_12_094452
5	CASI_2007_09_12_095125
6	CASI_2007_09_12_095920
7	CASI_2007_09_12_100608
8	CASI_2007_09_12_101440
9	CASI_2007_09_12_102910
10	CASI_2007_09_12_103536
11	CASI_2007_09_12_104328
12	CASI_2007_09_12_105055
13	CASI_2007_09_12_105839
14	CASI_2007_09_12_110656
15	CASI_2007_09_12_111528
16	CASI_2007_09_12_112438
17	CASI_2007_09_12_113257
18	CASI_2007_09_12_114104
19	CASI_2007_09_12_121005
20	CASI_2007_09_12_121906
21	CASI_2007_09_12_152043
22	CASI_2007_09_12_153227
23	CASI_2007_09_12_154918
24	CASI_2007_09_12_160500
25	CASI_2007_09_12_161627
26	CASI_2007_09_12_163015
27	CASI_2007_09_12_164212
28	CASI_2007_09_12_165538

Meterological Data September 12, 2007	
Precip (mm)	0
Max Temp. (°C)	31
Min Temp. (°C)	17
Mean Temp. (°C)	25
Wind Speed (m/s)	1.48
Wind Dir (deg.)	8
Vapor Press. (mb)	16.74
Solar Rad. (KJ/m^2)	22145
PAR (uE/m^2)	15996

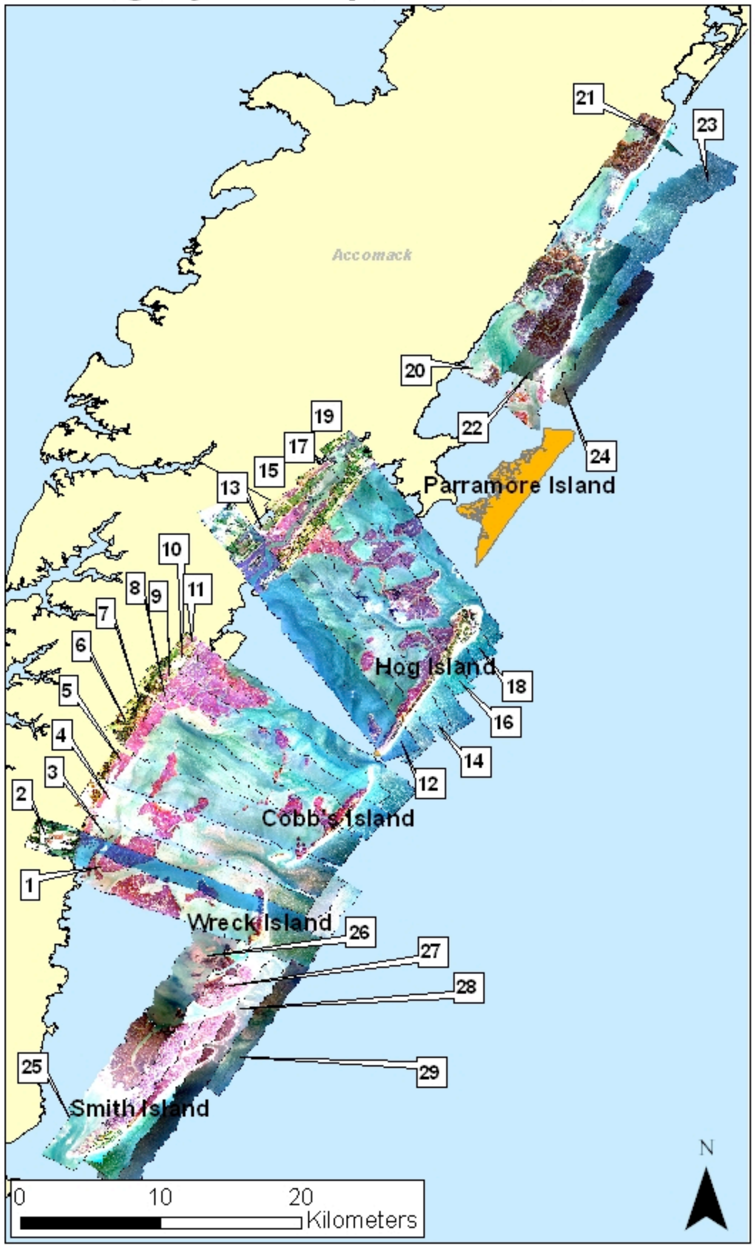


Coordinate System: GCS_WGS_1984
(Source Data: NRL, ESRI, LTER)

VCR 2007 CASI Imagery: 13-September-2007

Legend

- VCR Study Islands
- Virginia
- Ocean Background

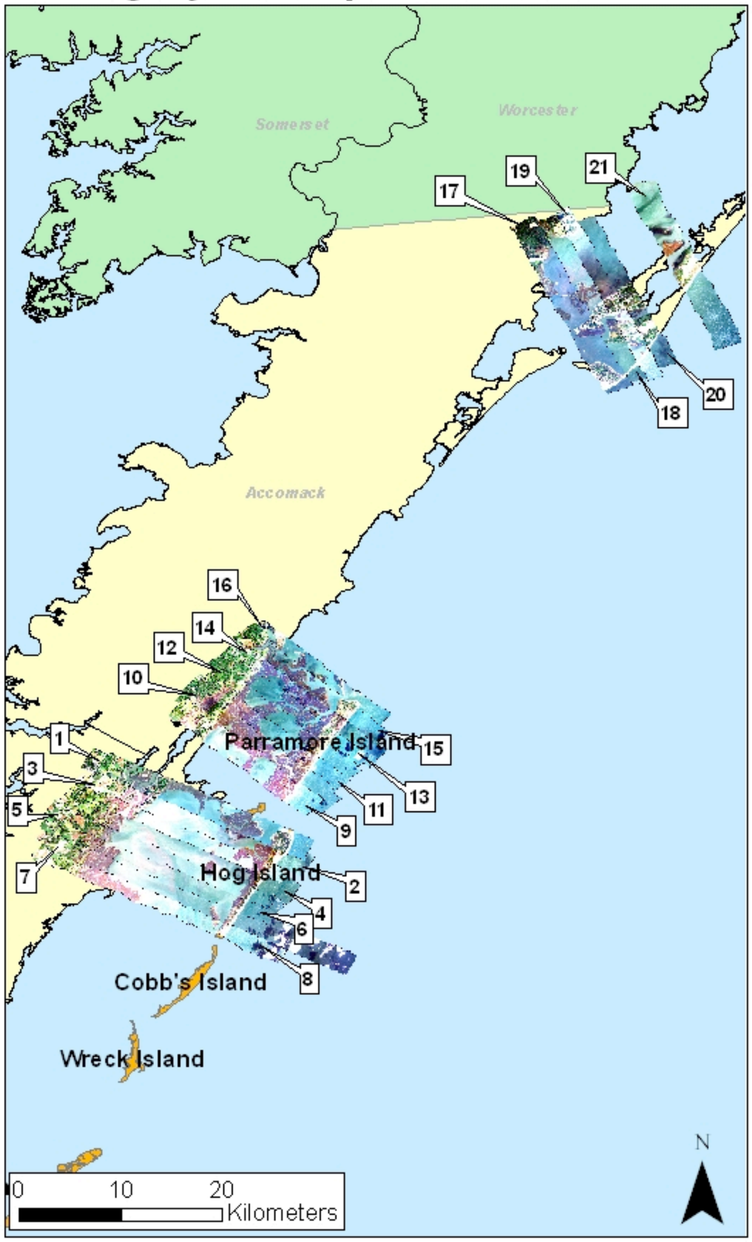


Index	Flight Line Name
1	CASI_2007_09_13_093136
2	CASI_2007_09_13_093728
3	CASI_2007_09_13_094527
4	CASI_2007_09_13_095916
5	CASI_2007_09_13_101310
6	CASI_2007_09_13_103026
7	CASI_2007_09_13_103713
8	CASI_2007_09_13_104545
9	CASI_2007_09_13_105151
10	CASI_2007_09_13_105945
11	CASI_2007_09_13_110638
12	CASI_2007_09_13_111658
13	CASI_2007_09_13_112459
14	CASI_2007_09_13_113313
15	CASI_2007_09_13_114024
16	CASI_2007_09_13_114816
17	CASI_2007_09_13_115501
18	CASI_2007_09_13_120247
19	CASI_2007_09_13_120947
20	CASI_2007_09_13_140645
21	CASI_2007_09_13_141459
22	CASI_2007_09_13_142451
23	CASI_2007_09_13_143121
24	CASI_2007_09_13_144106
25	CASI_2007_09_13_145743
26	CASI_2007_09_13_150714
27	CASI_2007_09_13_151650
28	CASI_2007_09_13_152604
29	CASI_2007_09_13_153532

Meterological Data September 13, 2007	
Precip (mm)	0
Max Temp. (°C)	29
Min Temp. (°C)	15
Mean Temp. (°C)	22.7
Wind Speed (m/s)	0.93
Wind Dir (deg.)	250
Vapor Press. (mb)	17.05
Solar Rad. (K J/m^2)	21367
PAR (uE/m^2)	15252

Coordinate System: GCS_WGS_1984
(Source Data: NRL, ESRI, LTER)

VCR 2007 CASI Imagery: 16-September-2007



Index	*Flight Line Name*
1	CASI_2007_09_16_091937
2	CASI_2007_09_16_092658
3	CASI_2007_09_16_093558
4	CASI_2007_09_16_094334
5	CASI_2007_09_16_095307
6	CASI_2007_09_16_100102
7	CASI_2007_09_16_101018
8	CASI_2007_09_16_102111
9	CASI_2007_09_16_103537
10	CASI_2007_09_16_104355
11	CASI_2007_09_16_105218
12	CASI_2007_09_16_105958
13	CASI_2007_09_16_110800
14	CASI_2007_09_16_111420
15	CASI_2007_09_16_112132
16	CASI_2007_09_16_112723
17	CASI_2007_09_16_114404
18	CASI_2007_09_16_115220
19	CASI_2007_09_16_115916
20	CASI_2007_09_16_120748
21	CASI_2007_09_16_123815

Meterological Data September 16, 2007	
Precip (mm)	0
Max Temp. (°C)	25
Min Temp. (°C)	18
Mean Temp. (°C)	22.1
Wind Speed (m/s)	2.92
Wind Dir (deg.)	37
Vapor Press. (mb)	18.3
Solar Rad. (KJ/m^2)	19900
PAR (uE/m^2)	18983

Coordinate System: GCS_WGS_1984
(Source Data: NRL, ESRI, LTER)

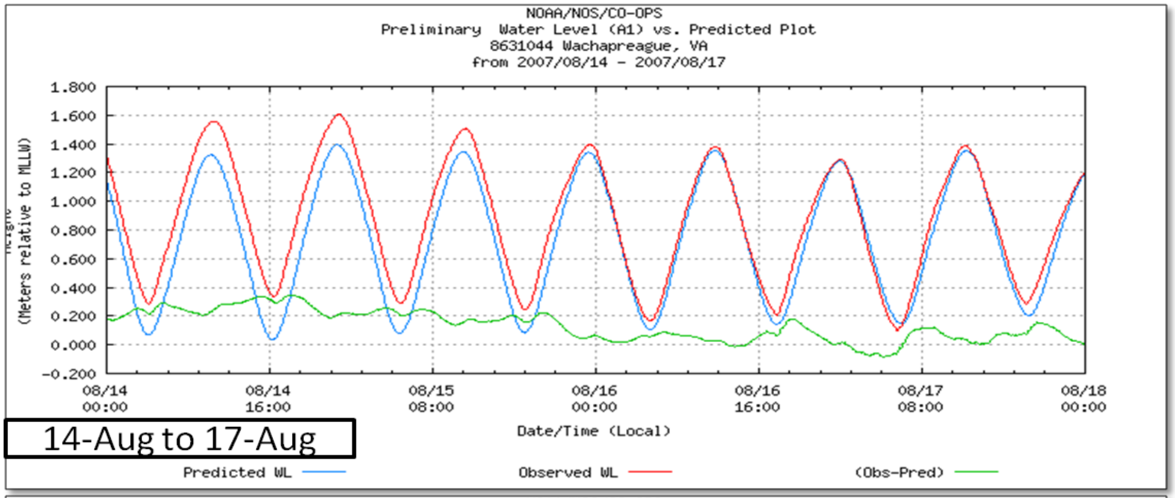
APPENDIX D

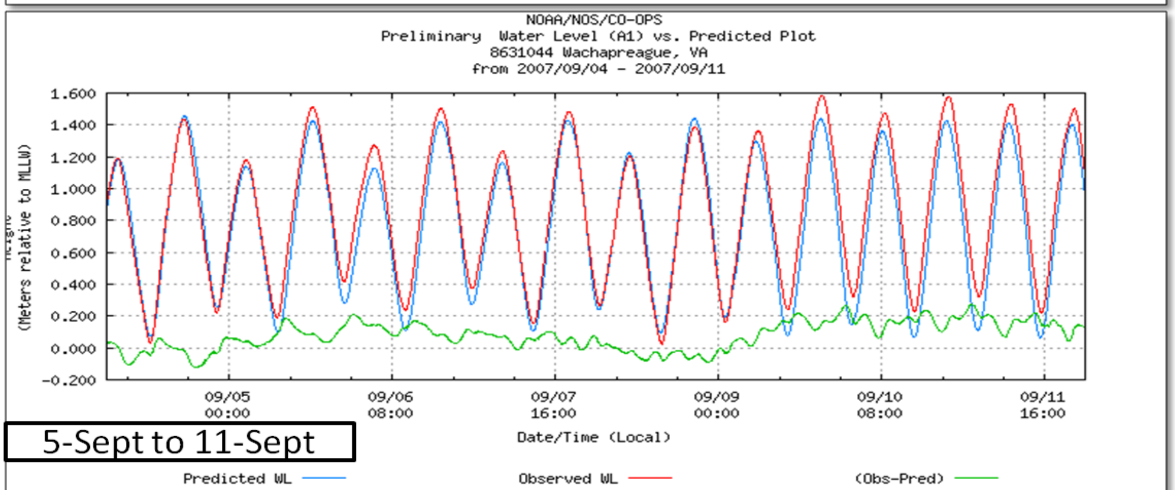
Water Level Data

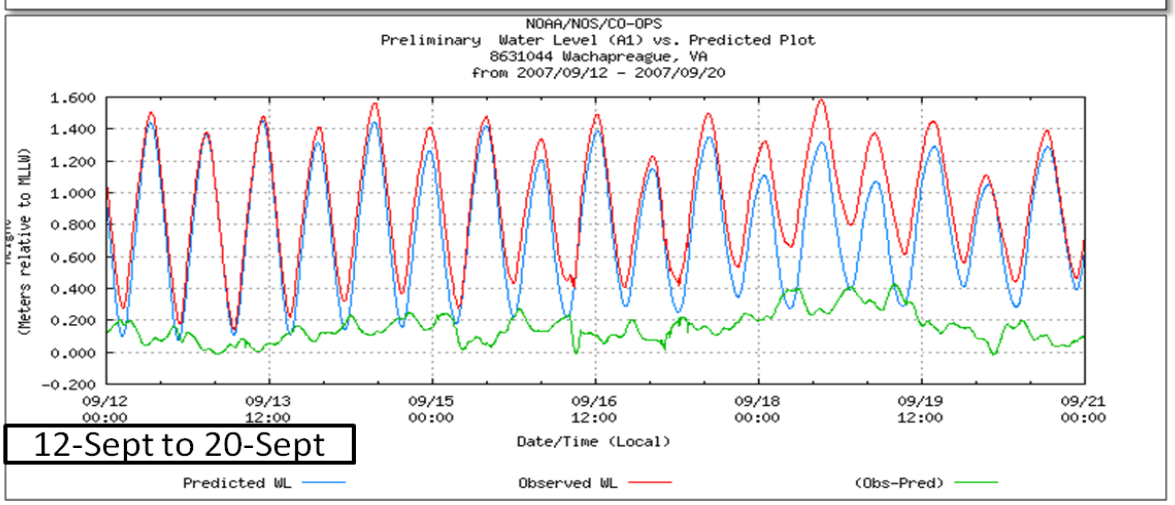
1. Introduction

Water level data are important for calibration and validation of bathymetry models. Water level data were provided by NOAA and were collected at the tide station located at Wachapreague, VA (37° 36.4' N, 75° 41.2' W; Station ID: 8631044). In Section 2 the water level is shown for the study period. The study period is divided into three date periods; period one (14-Aug to 17-Aug); period two (4-Sept to 11-Sept) and period three (12-Sept to 20-Sept). In Section 2, on the y-axis, the tide level in meters is displayed with relative levels to Mean Low or Low Water (MLLW). The x-axis displays the date and local time (LDT). Wachapreague, VA is located in the Eastern Time Zone of the United States. Section 3 shows a photograph of the Wachapreague, VA tide station.

2. Water Level Data







3. Wachapreague Water Level Station (NOAA)

APPENDIX E

Spectra

1. Introduction

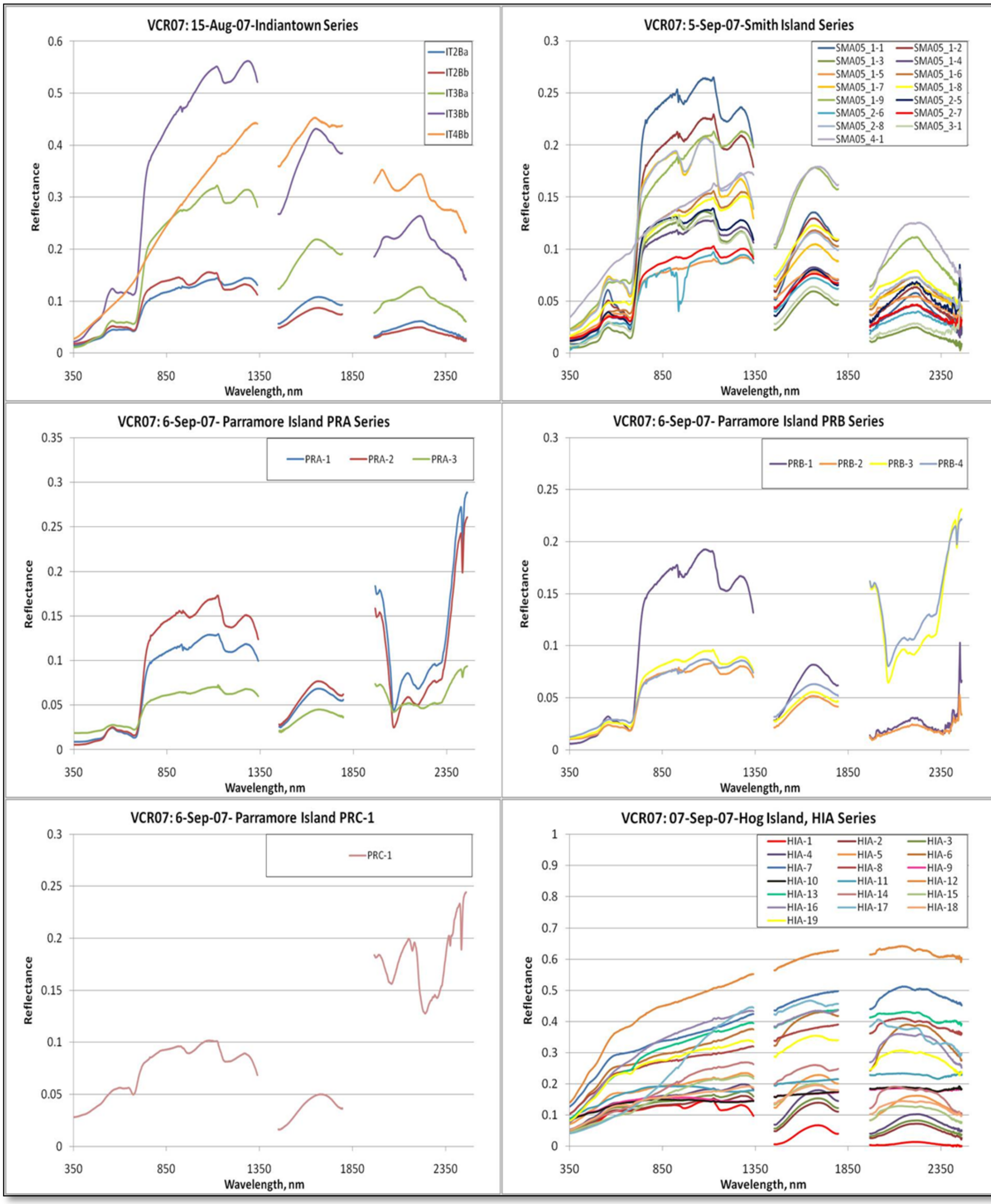
The reflectance spectra were measured with Analytical Spectral Devices (ASD) portable field spectrometers covering the range from 0.35 to 2.5 µm. Spectra measured with the ASD spectrometers in the field used passive solar illumination and a fiber-optic probe to collect light. The solar zenith incidence angle was variable but typically ranged from 40 to 60 degrees. Spectra were corrected to absolute reflectance by comparison against a Spectralon® white reference standard. Field spectra have been collected under various sky conditions. Most were collected under optimum conditions of clear skies and within the range of solar zenith angles listed above. Because of limited time for field work, some spectra were collected under partly cloudy skies and less than optimal solar zenith angles.

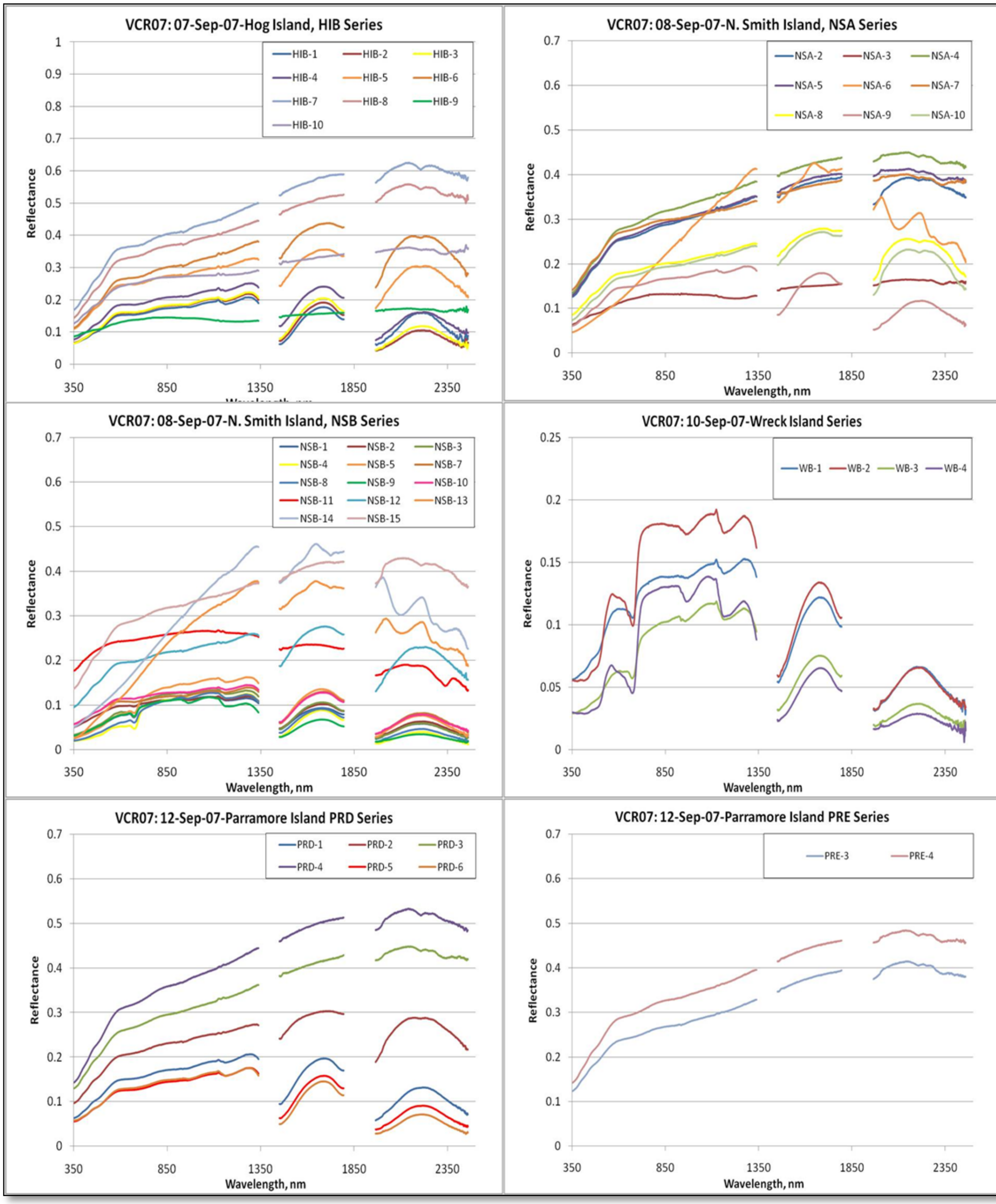
The spectra were edited to eliminate spectral regions with very high atmospheric water vapor absorption; these regions have low digital number counts and ratios between the spectral response of the white plaque and the specimen are often unstable in these spectral regions. The regions of editing were roughly from 1.35 µm to 1.44 µm, 1.79 µm to 1.95 µm and 2.45 µm to 2.5 µm.

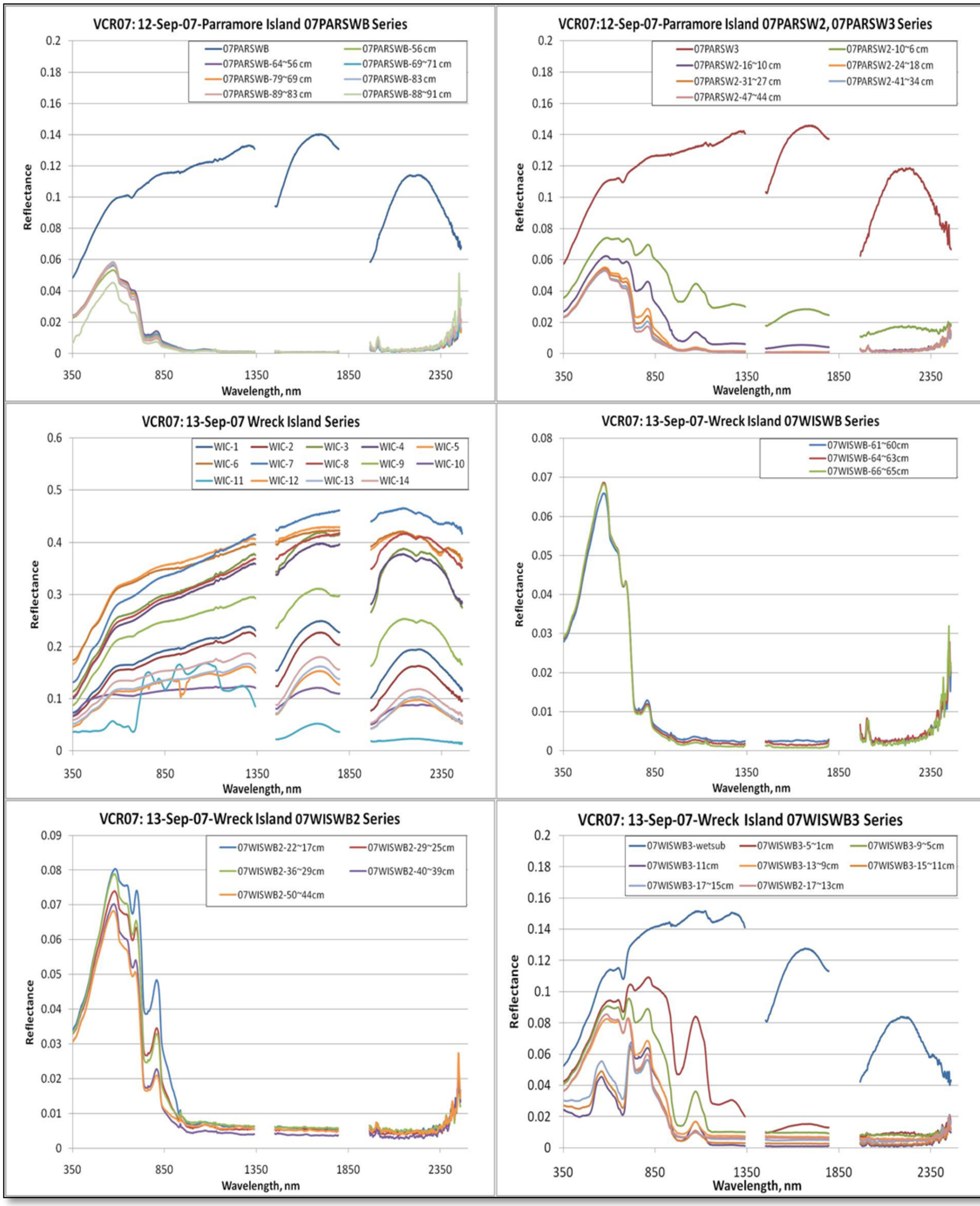
The digital spectral library data is a component of the geodatabase. The following graphs in Section 2 display the spectra as reflectance as a function of wavelength. The graphs display the spectra taken at a location on a specific date, which is indicated at the top of the graph. Similar data collected on the same date and location are grouped as a series and plotted together in the graphs. The graphs are listed in chronological order.

When spectra are collected it is important to take a photograph of the site being sampled. Each location where spectra were taken has a photograph in Section 3. These photographs show the substrate or general area of where each spectrum was taken. The photographs are listed in alphabetical order by site name.

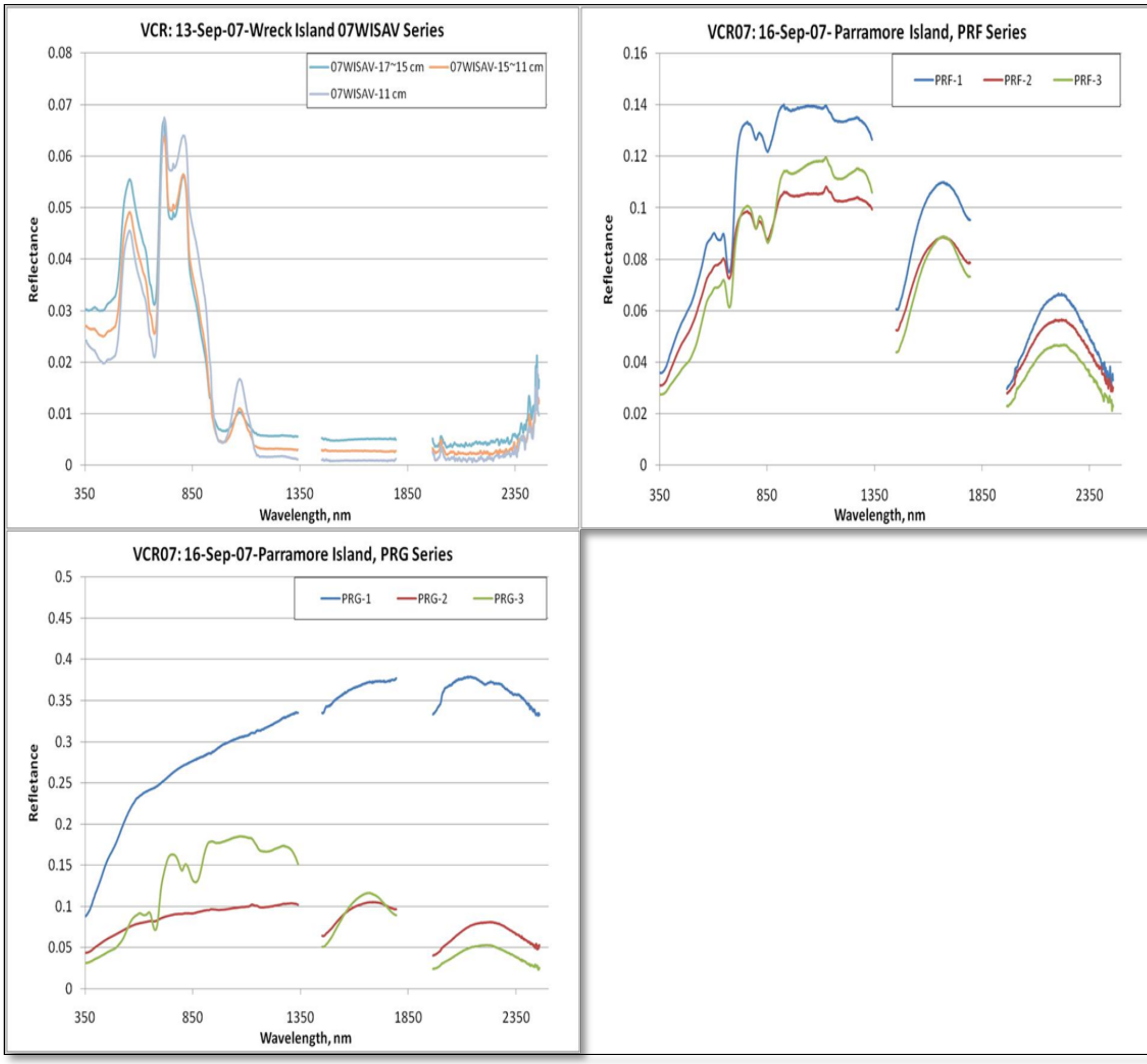
2. Reflectance Spectra




VCR07: 07-Sep-07-Hog Island, HIB Series
HIB-1
HIB-2
HIB-3
HIB-4
HIB-5
HIB-6
HIB-7
HIB-8
HIB-9
HIB-10
Reflectance
VCR07: 08-Sep-07-N. Smith Island, NSA Series
NSA-2
NSA-3
NSA-4
NSA-5
NSA-6
NSA-7
NSA-8
NSA-9
NSA-10
Reflectance
Wavelength, nm
VCR07: 08-Sep-07-N. Smith Island, NSB Series
NSB-1
NSB-2
NSB-3
NSB-4
NSB-5
NSB-7
NSB-8
NSB-9
NSB-10
NSB-11
NSB-12
NSB-13
NSB-14
NSB-15
Reflectance
Wavelength, nm
VCR07: 10-Sep-07-Wreck Island Series
WB-1
WB-2
WB-3
WB-4
Reflectance
Wavelength, nm
VCR07: 12-Sep-07-Parramore Island PRD Series
PRD-1
PRD-2
PRD-3
PRD-4
PRD-5
PRD-6
Reflectance
Wavelength, nm
VCR07: 12-Sep-07-Parramore Island PRE Series
PRE-3
PRE-4
Reflectance
Wavelength, nm



VCR07: 12-Sep-07-Parramore Island 07PARSWB Series
07PARSWB
07PARSWB-56 cm
07PARSWB-64~56 cm
07PARSWB-69~71 cm
07PARSWB-79~69 cm
07PARSWB-83 cm
07PARSWB-89~83 cm
07PARSWB-88~91 cm
Reflectance
Wavelength, nm
VCR07:12-Sep-07-Parramore Island 07PARSW2, 07PARSW3 Series
07PARSW3
07PARSW2-10~6 cm
07PARSW2-16~10 cm
07PARSW2-24~18 cm
07PARSW2-31~27 cm
07PARSW2-41~34 cm
07PARSW2-47~44 cm
Reflectnace
Wavelength, nm
VCR07: 13-Sep-07 Wreck Island Series
WIC-1
WIC-2
WIC-3
WIC-4
WIC-5
WIC-6
WIC-7
WIC-8
WIC-9
WIC-10
WIC-11
WIC-12
WIC-13
WIC-14
Reflectance
Wavelength, nm
VCR07: 13-Sep-07-Wreck Island 07WISWB Series
07WISWB-61~60cm
07WISWB-64~63cm
07WISWB-66~65cm
Reflectance
Wavelength, nm
VCR07: 13-Sep-07-Wreck Island 07WISWB2 Series
07WISWB2-22~17cm
07WISWB2-29~25cm
07WISWB2-36~29cm
07WISWB2-40~39cm
07WISWB2-50~44cm
Reflectance
Wavelength, nm
VCR07: 13-Sep-07-Wreck Island 07WISWB3 Series
07WISWB3-wetsub
07WISWB3-5~1cm
07WISWB3-9~5cm
07WISWB3-11cm
07WISWB3-13~9cm
07WISWB3-15~11cm
07WISWB3-17~15cm
07WISWB2-17~13cm
Reflectance
Wavelength, nm



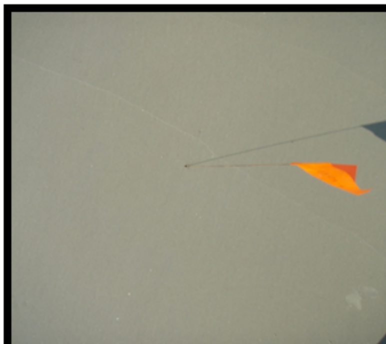
VCR: 13-Sep-07-Wreck Island 07WISAV Series
07WISAV-17~15 cm
07WISAV-15~11 cm
07WISAV-11 cm
Reflectance
Wavelength, nm
VCR07: 16-Sep-07- Parramore Island, PRF Series
PRF-1
PRF-2
PRF-3
Reflectance
Wavelength, nm
VCR07: 16-Sep-07-Parramore Island, PRG Series
PRG-1
PRG-2
PRG-3
Refletance
Wavelength, nm

3. Site Photographs


HIA-1


HIA-2


HIA-3

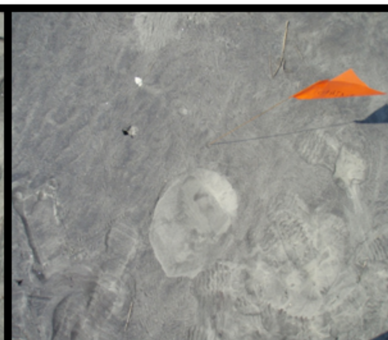

HIA-4

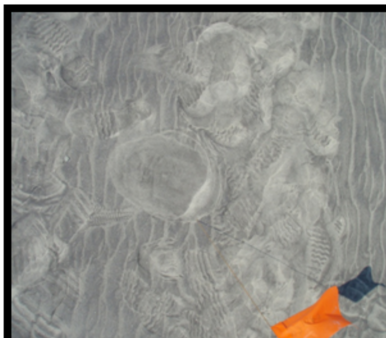

HIA-5


HIA-6


HIA-7


HIA-8


HIA-9


HIA-10


HIA-11


HIA-12


HIA-13


HIA-14

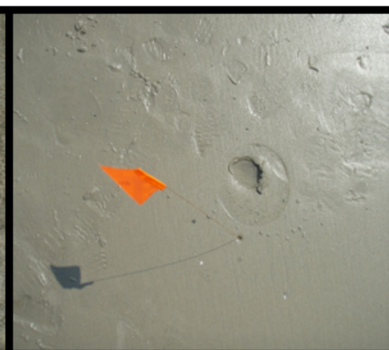

HIA-15


HIA-16


HIA-17


HIA-18


HIA-19

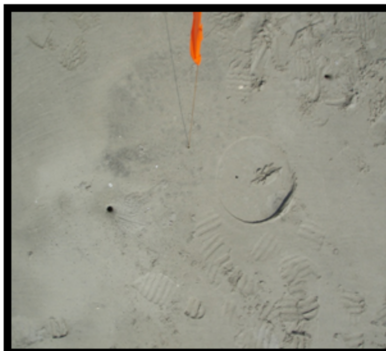

HIB-1


HIB-2


HIB-3


HIB-4

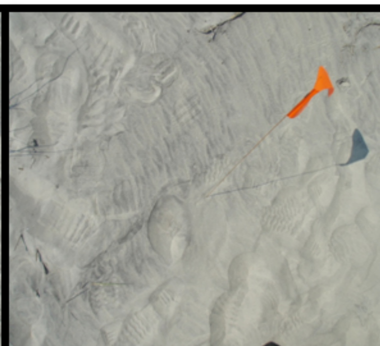

HIB-5


HIB-6


HIB-7


HIB-8


HIB-9


HIB-10


IT2Ba

IT2Bb


IT3Ba


IT3Bb


IT4Ba


IT4Bb


NSA-1

NSA-2

NSA-3

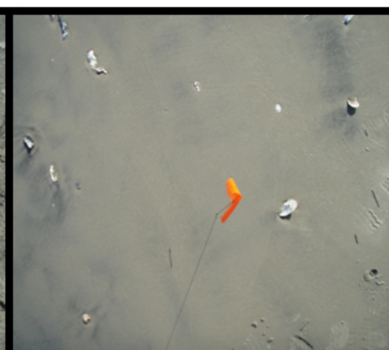
NSA-4

NSA-5

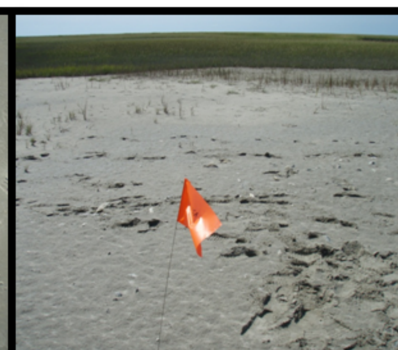
NSA-6

NSA-7

NSA-8

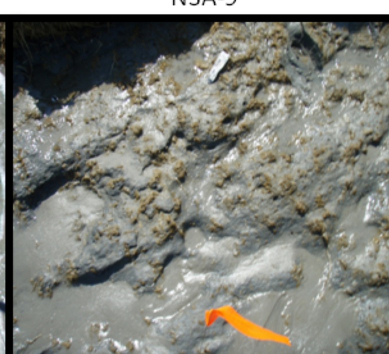


NSA-9



NSA-10

NSB-1



NSB-2

NSB-3

NSB-4

NSB-5

NSB-7

NSB-8

NSB-9

NSB-10

NSB-11

NSB-12

NSB-13

NSB-14

PARSWB

PRA-1


PRA-2


PRA-3


PRB-1


PRB-2


PRB-3


PRB-4

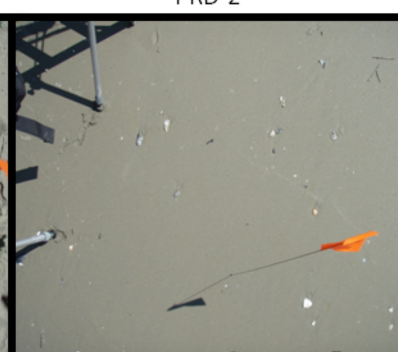

PRC-1

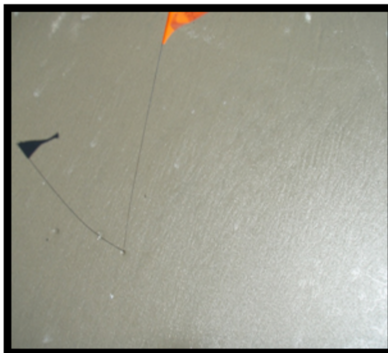

PRD-1


PRD-2


PRD-3


PRD-4


PRD-5


PRD-6


PRE-3


PRE-4


PRF-1


PRF-2


PRF-3


PRG-1


PRG-2


PRG-3


PRS


SMA05_1-1


SMA05_1-2

SMA05_1-3

SMA05_1-4

SMA05_1-5

SMA05_1-6

SMA05_1-6

SMA05_1-7

SMA05_1-8

SMA05_1-9

SMA05_2-5

SMA05_2-6

SMA05_2-8

SMA05_2-7


SMA05_2-9


SMA05_3-1


WB-1


WB-2

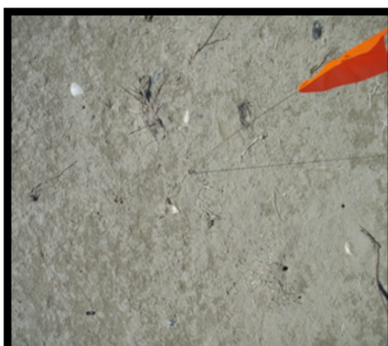

WB-3

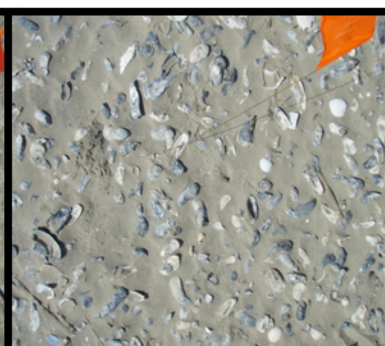

WB-4


WIC-1


WIC-2


WIC-3


WIC-4


WIC-5


WIC-6


WIC-7


WIC-8


WIC-9


WIC-10


WIC-11


WIC-12


WIC-13


WIC-14


WI-SAV


WI-SWB

APPENDIX F

Dynamic Modulus

1. Introduction

A light weight deflectometer (LWD) is an instrument that includes components such as a weight-fix-and-release mechanism, guide rod, falling weight, steel spring, and a base plate with an embedded accelerometer. Once the weight drops, the spring provides the buffer system that transmits the load pulse to the plate resting on the material to be tested. The weight is raised to a fixed height that, when dropped, will impart the desired force pulse. After the weight has recoiled from the base plate, the resulting vertical surface deflection is measured.

The Zorn ZFG 2000 LWD, with a 10-Kg (22.05 lbs) weight and a 300 mm (11.8 in) diameter plate was used to conduct plate-bearing tests during VCR'07. The LWD was used to measure bearing capacity (dynamic deflection modulus), one of the two failure mechanisms of soil under load. It is highly portable and was easily transported around the coastal zone. The Zorn ZFG 2000 provides a simple way to estimating bearing capacity and the recorder/printer device gives hard copy results in the field as well as recording data onto a chip card for uploading to a PC.

Light weight deflectometer data are seen below in tabular and graphical format. The data table provides the number of the test, the date and time, deflection values, dynamic modulus, and site name. The site names are grouped alphanumerically by transect. The graphs illustrate deflection in mm on the *y*-axis and time in milliseconds (ms) on the *x*-axis.

2. LWD Data Table

No. (of test)	Local Date	Local Time	Deflection [mm]				Evd [MN/m²]	Site Name
			single values			mean		
			s1	s2	s3	s		
1	15-Aug-07	09:56	8.676	8.095	7.983	8.251	2.7	IT2Ba
2	15-Aug-07	09:58	11.343	9.419	9.295	10.019	2.2	IT2Ba_Veg
5	15-Aug-07	10:53	10.636	7.850	7.553	8.680	2.6	IT3Ba
6	15-Aug-07	10:56	15.655	11.454	10.984	12.698	1.8	IT3Ba_Veg
3	15-Aug-07	10:33	15.355	10.002	9.816	11.724	1.9	IT3Bb
4	15-Aug-07	10:36	16.499	12.074	11.237	13.270	1.7	IT3Bb_Veg
7	15-Aug-07	11:14	11.027	7.090	6.873	8.330	2.7	IT4Bb
8	15-Aug-07	11:17	20.138	12.722	12.547	15.136	1.5	IT4Bb_Veg
9	15-Aug-07	11:19	17.607	12.994	12.339	14.313	1.6	IT4Bb_Veg_New_Spot
7	16-Aug-07	09:00	17.280	13.726	13.761	14.922	1.5	CLCa_CreekBank
8	16-Aug-07	09:07	14.098	9.138	9.025	10.754	2.1	CLCa_Low Marsh
6	16-Aug-07	08:53	11.869	12.071	12.009	11.983	1.9	CLCb_CreekBank
9	16-Aug-07	09:12	9.363	9.091	9.616	9.357	2.4	CLCb_Low Marsh
3	16-Aug-07	08:28	11.168	10.945	11.318	11.144	2.0	Betw CL1Aa and Ab
2	16-Aug-07	08:25	10.125	10.945	11.268	10.779	2.1	CL1Aa
1	16-Aug-07	08:21	12.481	11.327	11.592	11.800	1.9	CL1Ab
11	16-Aug-07	09:28	12.452	5.566	3.883	7.300	3.1	CL3Ba
12	16-Aug-07	09:35	8.416	3.161	5.960	5.846	3.8	CL3Bb
14	16-Aug-07	09:52	18.477	14.571	14.006	15.685	1.4	CL4Ba
13	16-Aug-07	09:47	8.984	7.647	15.733	10.788	2.1	CL4Bb
17	16-Aug-07	10:03	17.898	17.480	16.762	17.380	1.3	CL4Ca
15	16-Aug-07	09:59	2.099	17.465	16.781	12.115	1.9	CL4Cb
16	16-Aug-07	10:01	15.898	16.047	16.364	16.103	1.4	CL4Cb

No. (of test)	Local Date	Local Time	Deflection [mm]				Evd [MN/m²]	Site Name
			single values			mean		
			s1	s2	s3	s		
27	5-Sep-07	12:17	2.135	18.870	13.210	11.405	2.0	SMA05-1-1 Take 1
28	5-Sep-07	12:20	15.278	8.366	8.494	10.713	2.1	SMA05-1-1 Take 2
29	5-Sep-07	12:22	17.278	9.971	9.191	12.147	1.9	SMA05-1-1 Take 3
30	5-Sep-07	14:20	14.496	8.494	8.723	10.571	2.1	SMA05-1-8_Veg-off
31	5-Sep-07	14:15	14.359	9.692	10.159	11.403	2.0	SMA05-1-8_Veg-on
32	5-Sep-07	13:54	10.696	10.272	10.359	10.442	2.2	SMA05-1-9_Veg-off
33	5-Sep-07	13:57	14.093	10.220	10.487	11.600	1.9	SMA05-1-9_Veg-on
34	5-Sep-07	14:02	9.617	9.929	10.400	9.982	2.3	SMA05-4-1
35	5-Sep-07	14:08	8.535	8.721	9.081	8.779	2.6	SMA05-4-2
3	6-Sep-07	11:06	4.917	15.736	13.992	11.548	1.9	PRA-1_Veg_off
1	6-Sep-07	10:56	13.952	13.143	12.465	13.187	1.7	PRA-2_Veg_off
2	6-Sep-07	10:59	11.684	12.190	11.754	11.876	1.9	PRA-2_Veg_on
7	6-Sep-07	11:50	14.076	12.824	12.609	13.170	1.7	PRB-2_Veg_off
5	6-Sep-07	11:40	11.912	12.363	12.220	12.165	1.8	PRB-4_Veg-off
6	6-Sep-07	11:43	15.277	11.391	11.835	12.834	1.8	PRB-4_Veg-on
4	6-Sep-07	11:24	13.880	8.215	8.583	10.226	2.2	PRS

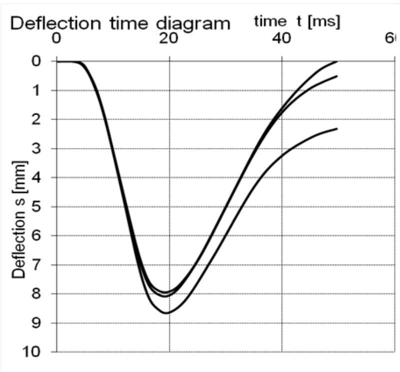
No. (of test)	Local Date	Local Time	Deflection [mm]				Evd [MN/m²]	Site Name
			single values			mean		
			s1	s2	s3	s		
8	7-Sep-07	11:03	0.964	0.923	0.893	0.927	24.3	07HIA-1
10	7-Sep-07	11:12	0.996	0.901	0.863	0.920	24.5	07HIA-2
9	7-Sep-07	11:09	0.120	0.941	0.892	0.651	34.6	07HIA-2 (instrument error ?)
13	7-Sep-07	11:20	0.947	0.839	0.782	0.856	26.3	07HIA-3
16	7-Sep-07	11:33	0.828	0.736	0.720	0.761	29.6	07HIA-4
17	7-Sep-07	11:36	0.802	0.649	0.623	0.691	32.6	07HIA-5
20	7-Sep-07	11:46	3.323	1.278	1.023	1.875	12.0	07HIA-6
21	7-Sep-07	11:48	2.363	1.236	1.000	1.533	14.7	07HIA-6, 2nd try
23	7-Sep-07	11:53	4.721	1.756	1.257	2.578	8.7	07HIA-7
22	7-Sep-07	11:50	7.401	1.188	1.176	3.255	6.9	07HIA-7 (bad first bounce)
26	7-Sep-07	12:02	9.747	3.211	3.301	5.420	4.2	07HIA-8 (bad first catch)
27	7-Sep-07	12:05	9.765	5.096	3.770	6.210	3.6	07HIA-8, 2nd try
28	7-Sep-07	12:08	6.597	2.052	1.890	3.513	6.4	07HIA-9
31	7-Sep-07	12:17	5.075	2.383	2.120	3.193	7.0	07HIA-10
34	7-Sep-07	13:15	4.683	2.474	1.992	3.050	7.4	07HIA-11
36	7-Sep-07	13:25	9.739	3.692	3.970	5.800	3.9	07HIA-12, 2nd of 3
37	7-Sep-07	13:27	8.938	4.742	4.256	5.979	3.8	07HIA-12, 3rd of 3
35	7-Sep-07	13:22	11.259	4.046	4.448	6.584	3.4	07HIA-12, bad 1st bounce
38	7-Sep-07	13:55	4.539	3.271	2.984	3.598	6.3	07HIA-13
40	7-Sep-07	14:46	2.171	9.335	2.806	4.771	4.7	07HIA-14
39	7-Sep-07	14:45	7.612	10.555	11.301	9.823	2.3	07HIA-14 BB
41	7-Sep-07	14:51	9.292	8.360	7.906	8.519	2.6	07HIA-15
42	7-Sep-07	14:58	8.865	6.573	5.981	7.140	3.2	07HIA-16
44	7-Sep-07	15:10	20.539	19.719	18.689	19.649	1.1	07HIA-17, 2nd try
43	7-Sep-07	15:09	21.798	20.485	18.894	20.392	1.1	07HIA-17, BB
45	7-Sep-07	15:17	7.622	5.922	5.333	6.292	3.6	07HIA-18
46	7-Sep-07	15:27	4.940	3.954	3.385	4.093	5.5	07HIA-19
11	7-Sep-07	11:15	0.926	0.830	0.828	0.861	26.1	07HIB-1
12	7-Sep-07	11:18	1.110	0.901	0.817	0.943	23.9	07HIB-2
15	7-Sep-07	11:28	1.097	0.843	0.964	0.968	23.2	07HIB-3
14	7-Sep-07	11:26	1.105	0.856	0.751	0.904	24.9	07HIB-3 (missed 2nd pulse)
18	7-Sep-07	11:38	0.887	0.686	0.663	0.745	30.2	07HIB-4 (south of HIA-5)
19	7-Sep-07	11:42	1.186	0.780	0.672	0.879	25.6	07HIB-5
24	7-Sep-07	11:57	3.741	1.746	1.250	2.246	10.0	07HIB-6
25	7-Sep-07	11:59	6.811	2.647	2.168	3.875	5.8	07HIB-7
29	7-Sep-07	12:10	6.995	4.956	4.076	5.342	4.2	07HIB-8
30	7-Sep-07	12:13	6.439	4.442	4.057	4.979	4.5	07HIB-8 (2nd try)
32	7-Sep-07	12:20	6.032	2.477	2.069	3.526	6.4	07HIB-9
33	7-Sep-07	12:28	3.465	1.727	1.374	2.189	10.3	07HIB-10

No. (of test)	Local Date	Local Time	Deflection [mm]				Evd [MN/m²]	Site Name
			single values			mean		
			s1	s2	s3	s		
2	8-Sep-07	10:01	7.295	3.758	3.678	4.910	4.6	07NSA-1
3	8-Sep-07	10:12	7.738	6.392	5.368	6.499	3.5	07NSA-2
4	8-Sep-07	10:22	3.593	3.137	2.643	3.124	7.2	07NSA-3
5	8-Sep-07	10:36	6.556	3.721	3.557	4.611	4.9	07NSA-4
6	8-Sep-07	10:48	10.003	7.414	6.679	8.032	2.8	07NSA-5
7	8-Sep-07	11:04	10.432	5.446	5.187	7.022	3.2	07NSA-6
8	8-Sep-07	11:10	4.694	3.107	2.841	3.547	6.3	07NSA-7
9	8-Sep-07	11:20	11.931	4.646	4.343	6.973	3.2	07NSA-8
1	8-Sep-07	09:48	1.156	0.842	0.787	0.928	24.2	07NSA-9
10	8-Sep-07	11:36	14.400	4.455	4.089	7.648	2.9	07NSA-10
14	8-Sep-07	12:35	15.744	14.759	14.421	14.975	1.5	07NSB-1
13	8-Sep-07	12:20	13.946	13.221	13.661	13.609	1.7	07NSB-2
11	8-Sep-07	11:54	14.002	12.995	13.688	13.562	1.7	07NSB-3, 1st try
12	8-Sep-07	12:03	16.603	11.839	11.689	13.377	1.7	07NSB-4
24	8-Sep-07	14:08	10.175	9.151	8.999	9.442	2.4	07NSB-5
15	8-Sep-07	13:13	1.591	1.666	1.746	1.668	13.5	07NSB-7
16	8-Sep-07	13:23	14.719	15.041	14.546	14.769	1.5	07NSB-8
17	8-Sep-07	13:34	17.284	12.566	12.326	14.059	1.6	07NSB-9
25	8-Sep-07	14:15	6.854	4.307	4.420	5.194	4.3	07NSB-10
21	8-Sep-07	13:58	13.530	6.627	4.430	8.196	2.7	07NSB-11 1st try
22	8-Sep-07	14:01	7.791	4.516	3.688	5.332	4.2	07NSB-11, 2nd try
23	8-Sep-07	14:03	10.106	4.692	4.361	6.386	3.5	07NSB-11, 3rd try
18	8-Sep-07	13:43	4.132	1.313	1.085	2.177	10.3	07NSB-12, 1st try
19	8-Sep-07	13:45	2.580	1.291	1.105	1.659	13.6	07NSB-12, 2nd try
20	8-Sep-07	13:47	2.303	1.218	1.114	1.545	14.6	07NSB-12, 3rd try
26	8-Sep-07	14:20	10.234	4.788	3.851	6.291	3.6	07NSB-13
27	8-Sep-07	14:22	18.859	17.308	16.139	17.435	1.3	07NSB-13_w rack
29	8-Sep-07	14:42	13.390	11.993	11.529	12.304	1.8	07NSB-14
28	8-Sep-07	14:32	7.393	1.788	1.538	3.573	6.3	07NSB-15
1	10-09-07	12:24	11.705	12.001	12.330	12.012	1.9	WB-1 1st try
2	10-09-07	12:31	12.130	11.569	11.611	11.770	1.9	WB-1 2nd try
3	10-09-07	12:43	9.042	10.141	10.705	9.963	2.3	WB-2
4	10-09-07	12:54	14.670	10.622	10.209	11.834	1.9	WB-3
5	10-09-07	13:41	10.423	10.890	11.280	10.864	2.1	WB-4
1	12-09-07	10:51	2.463	2.262	2.009	2.245	10.0	07PRD01
2	12-09-07	11:12	12.327	3.446	4.180	6.651	3.4	07PRD02- 1st try
3	12-09-07	11:15	10.830	5.258	3.975	6.688	3.4	07PRD02- 2nd try
4	12-09-07	11:37	6.158	4.365	4.102	4.875	4.6	07PRD03- 1st try
5	12-09-07	11:39	5.244	3.892	3.527	4.221	5.3	07PRD-03 2nd try
6	12-09-07	11:53	12.825	4.394	3.324	6.848	3.3	07PRD-04
7	12-09-07	12:06	1.289	1.087	0.996	1.124	20.0	07PRD-05
8	12-09-07	12:56	1.097	1.016	0.990	1.034	21.8	07PRD-06
11	12-09-07	14:04	6.280	4.348	3.995	4.874	4.6	07PRE-03 (repeated first pulse)
9	12-09-07	13:19	11.495	3.183	3.069	5.916	3.8	07PRE04 - 1st try
10	12-09-07	13:22	14.139	4.052	3.217	7.136	3.2	07PRE04- 2nd try

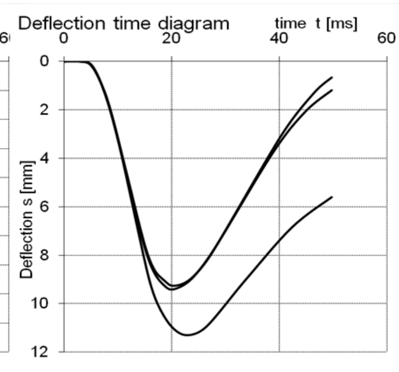
No. (of test)	Local Date	Local Time	Deflection [mm]				Evd [MN/m²]	Site Name
			single values			mean		
			s1	s2	s3	s		
21	13-09-07	13:11	6.825	1.405	1.232	3.154	7.1	WIC-1
12	13-09-07	10:07	1.700	1.341	1.277	1.439	15.6	WIC-2
13	13-09-07	10:26	5.053	2.532	1.939	3.175	7.1	WIC-3
14	13-09-07	10:39	6.075	2.499	1.886	3.487	6.5	WIC-4
15	13-09-07	10:50	8.099	2.820	2.163	4.361	5.2	WIC-5
16	13-09-07	11:00	4.745	2.733	2.211	3.230	7.0	WIC-6
17	13-09-07	11:15	8.390	4.190	4.036	5.539	4.1	WIC-7
18	13-09-07	11:31	7.253	6.302	5.915	6.490	3.5	WIC-8
19	13-09-07	11:49	6.357	5.298	5.139	5.598	4.0	WIC-9
20	13-09-07	12:04	6.658	6.215	6.436	6.436	3.5	WIC-10
NA	NA	NA	NA	NA	NA	NA	NA	WIC-11
22	13-09-07	13:48	2.321	1.537	1.380	1.746	12.9	WIC-12
23	13-09-07	14:04	2.198	1.609	1.578	1.795	12.5	WIC-13
24	13-09-07	14:14	2.030	1.574	1.447	1.684	13.4	WIC-14
1	16-09-07	09:54	11.114	12.388	12.469	11.990	1.9	07PRF-1
2	16-09-07	10:09	11.142	11.830	12.095	11.689	1.9	07PRF-2
3	16-09-07	10:15	11.319	11.877	11.807	11.668	1.9	07PRF-2 (repeat)
4	16-09-07	10:27	12.486	14.619	12.102	13.069	1.7	07PRF-3
5	16-09-07	10:34	12.776	12.781	12.696	12.751	1.8	07PRF-3 (repeat)
6	16-09-07	10:48	5.004	2.059	1.864	2.976	7.6	07PRG-1
7	16-09-07	11:01	6.748	6.766	6.860	6.791	3.3	07PRG-2
8	16-09-07	11:16	10.780	11.379	11.539	11.233	2.0	07PRG-3

3. LWD Graphs

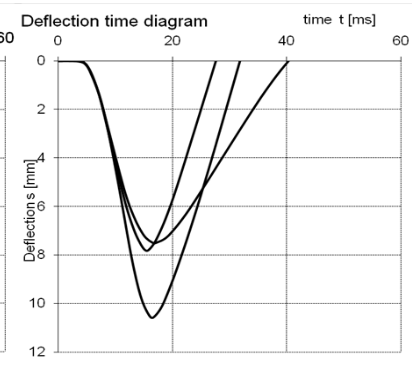
3.1. 15-Aug-2007-Indiantown (IT) Transect



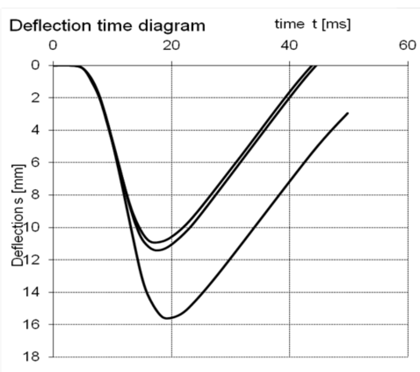
IT2Ba



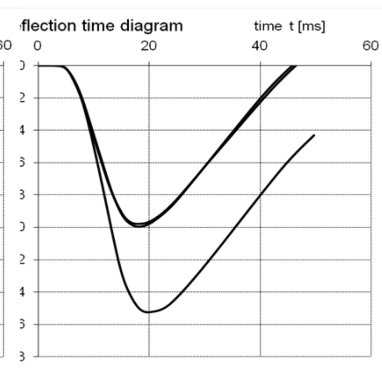
IT2Ba Veg



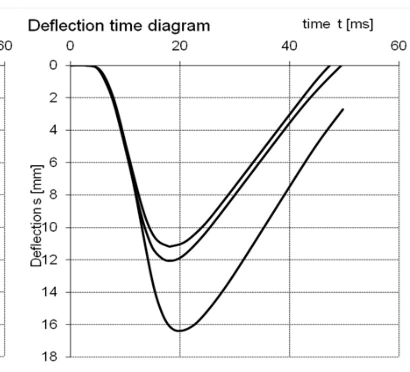
IT3Ba



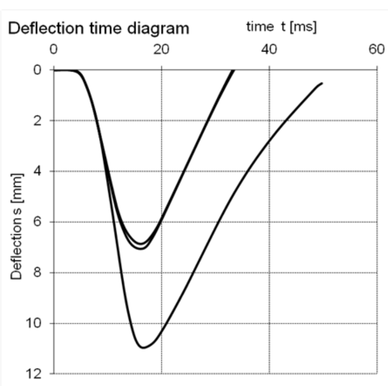
IT3Ba Veg



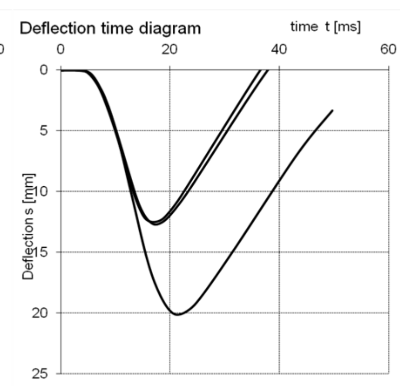
IT3Bb



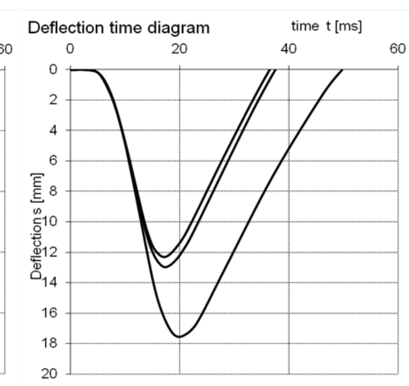
IT3Bb Veg



IT4Ba

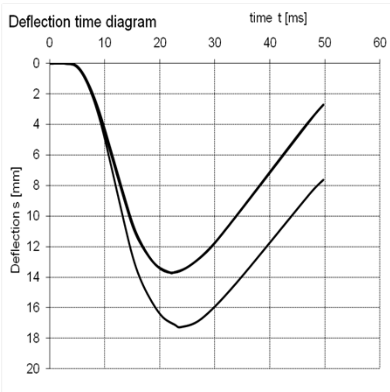


IT4Bb Veg

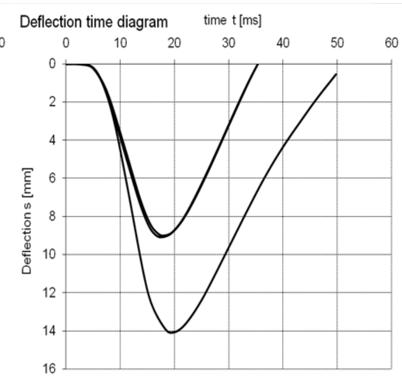


IT4Bb Veg New Spot

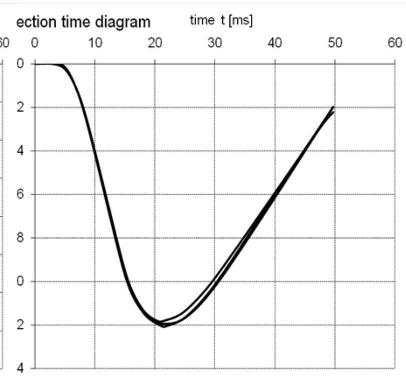
3.2.16-Aug-2007-Cushman's Landing (CL) Transect



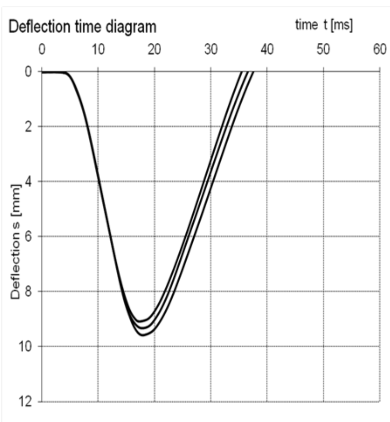
CLCa_CreekBank



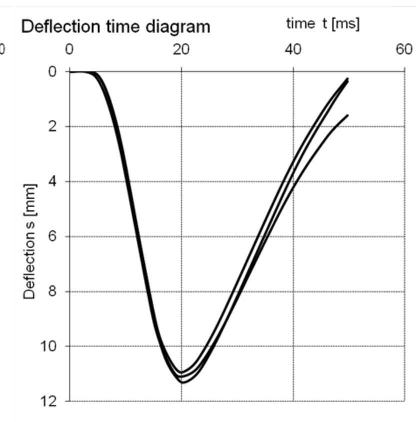
CLCa_LowMarsh



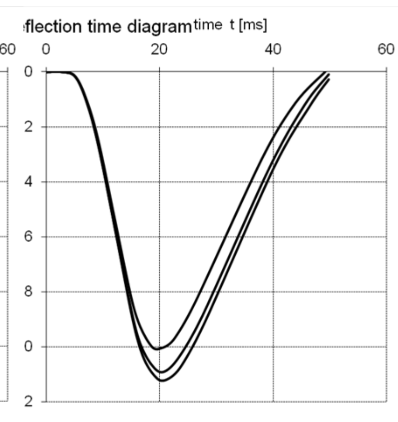
CLCb_CreekBank



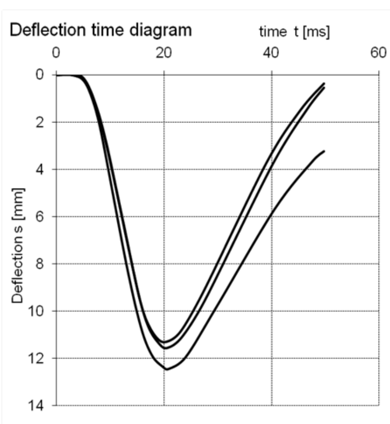
CLCb_LowMarsh



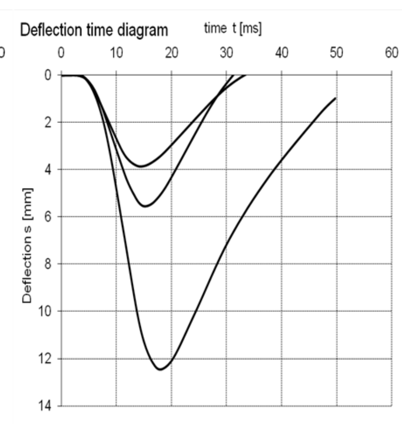
Betw. CL1Aa and Ab



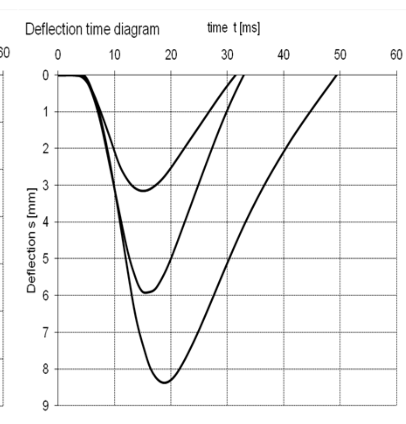
CL1Aa



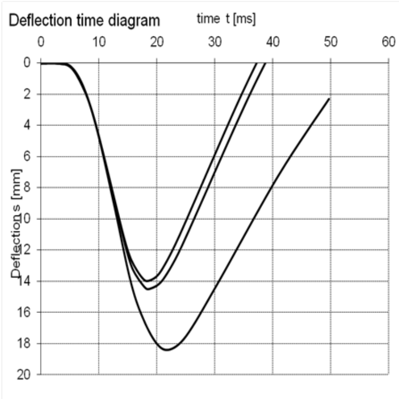
CL1Ab



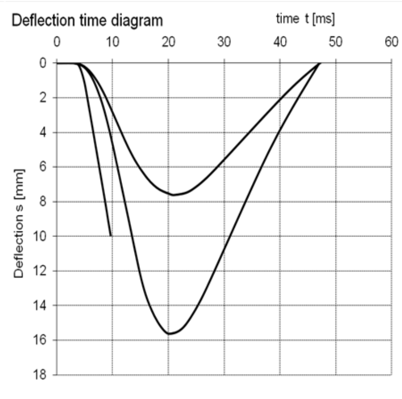
CL3Ba



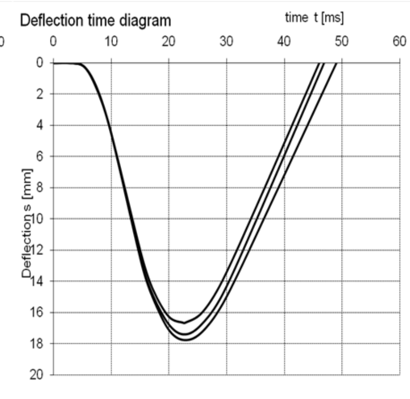
CL3Bb



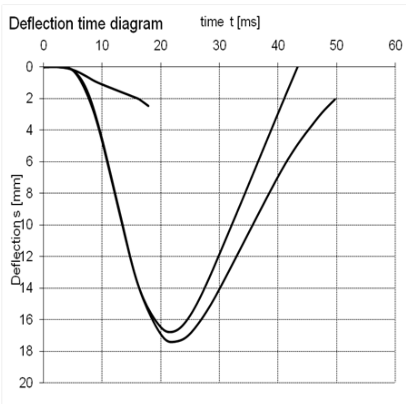
CL4Ba



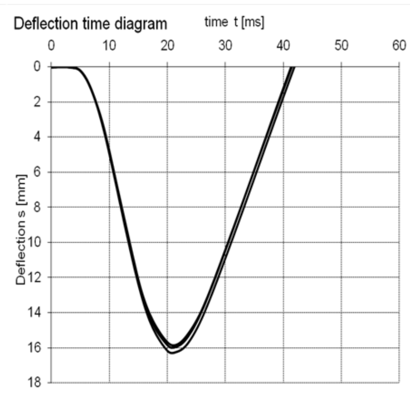
CL4Bb



CL4Ca

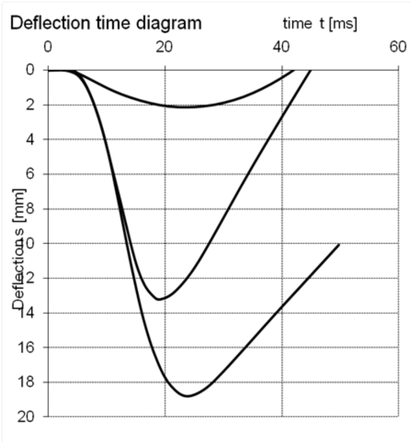


CL4Cb # 1

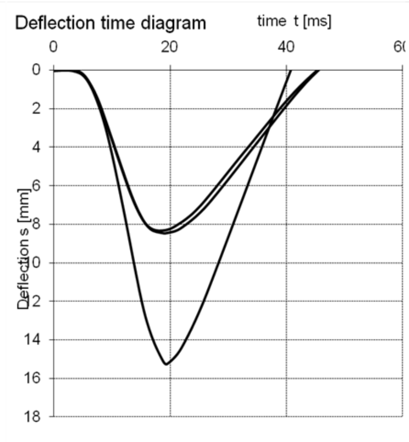


CLC4Cb # 2

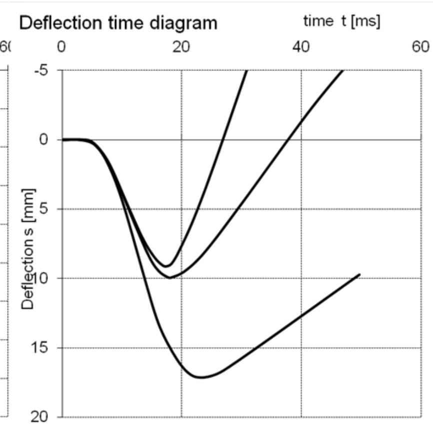
3.3. 5-Sep-2007-Smith Island (SMA05) Transect



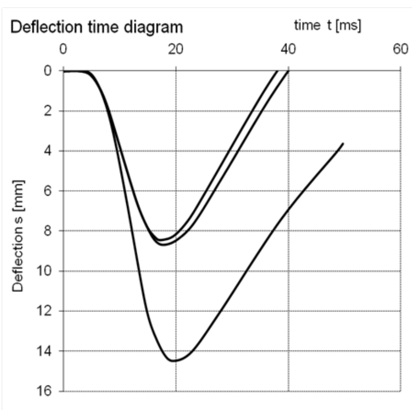
SMA05-1-1 Take 1



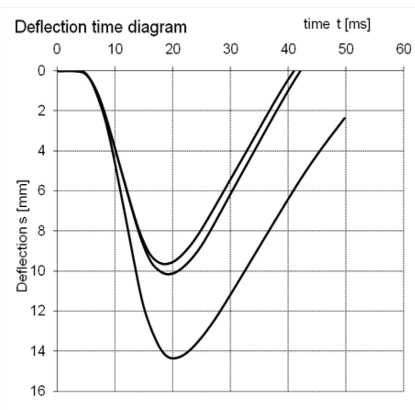
SMA05-1-1 Take 2



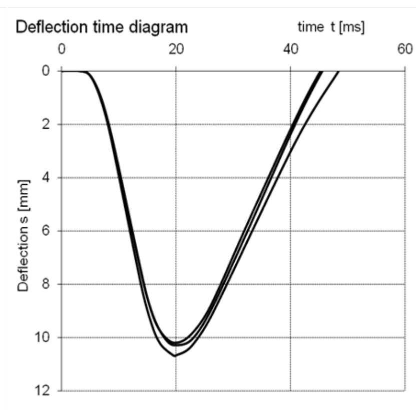
SMA05-1-1 Take 3



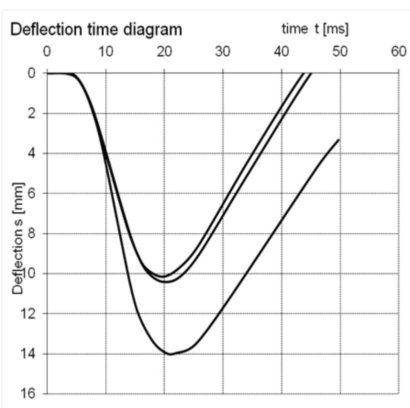
SMA05-1-8_Veg-off



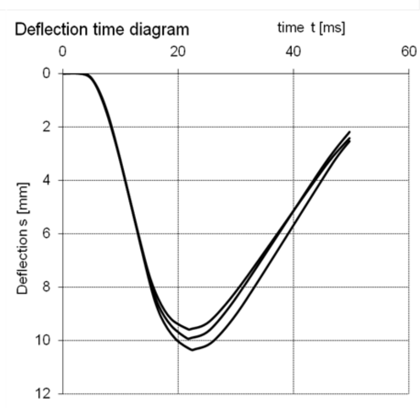
SMA05-1-8_Veg-on



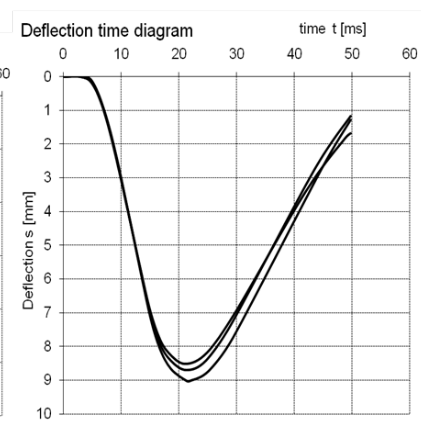
SMA05-1-9_Veg-off



SMA05-1-9_Veg-on

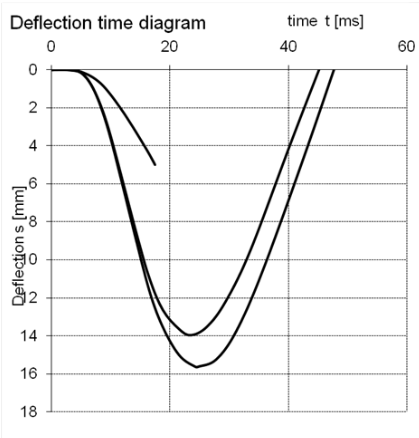


SMA05-4-1

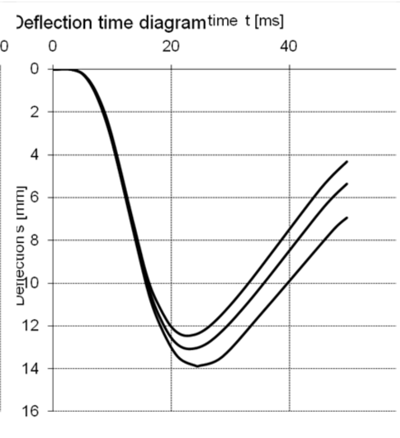


SMA05-4-2

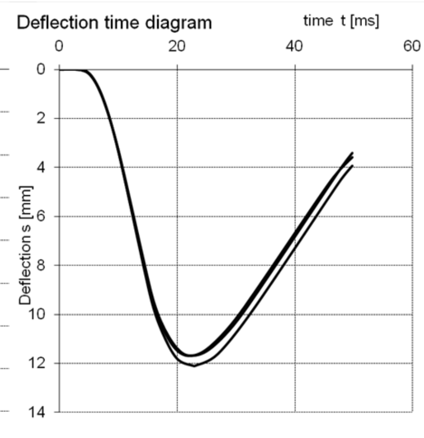
3.4. 6-Sep-2007-Parramore Island (PRA) Transect



PRA-1_Veg_off

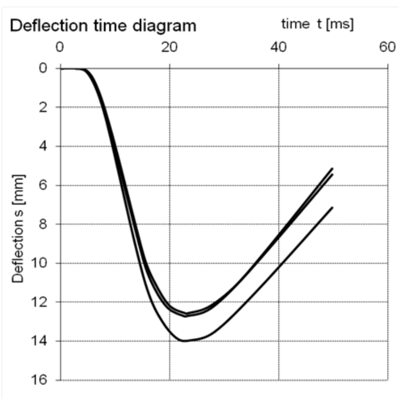


PRA-2_Veg_off

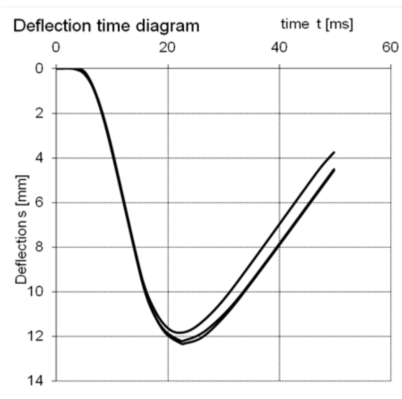


PRA-2_Veg_on

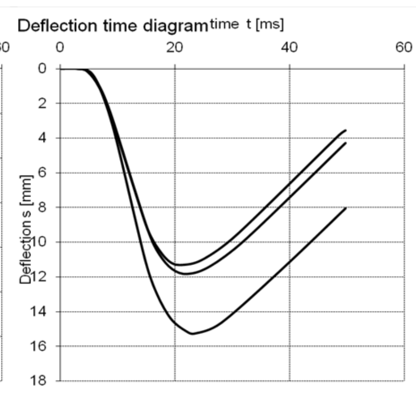
3.5. 6-Sep-2007-Parramore Island (PRB) Transect



PRB-2_Veg_off

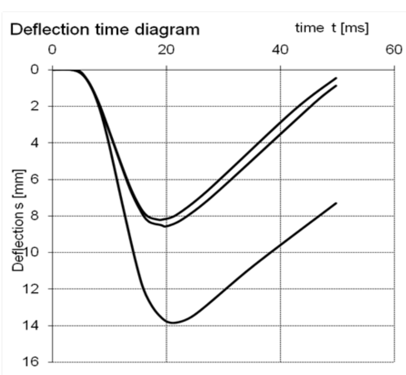


PRB-4_Veg_off



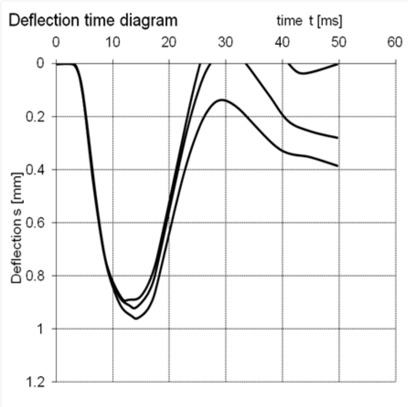
PRB-4_Veg_on

3.6. 6-Sep-2007-Parramore Island (PRS) Site

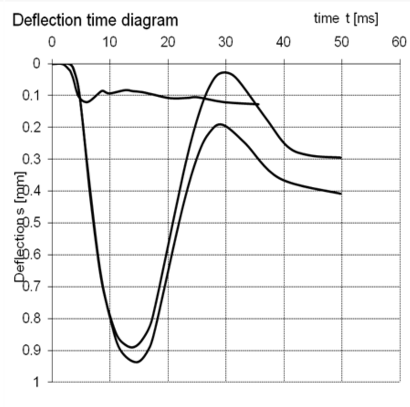


PRS

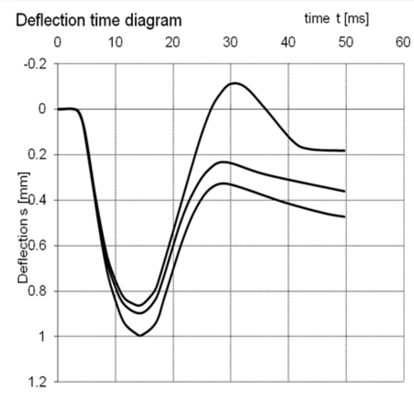
3.7. 7-Sep-2007-Hog Island (HIA) Transect



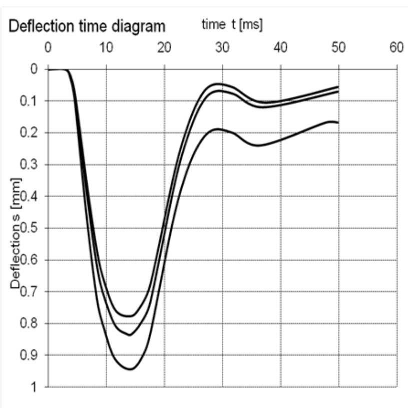
HIA-1



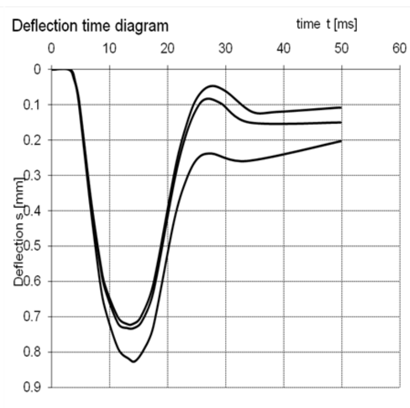
HIA-2 #1



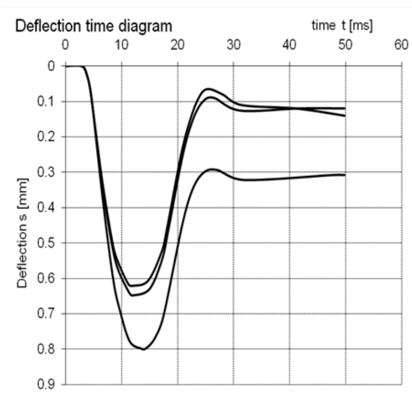
HIA-2 #2



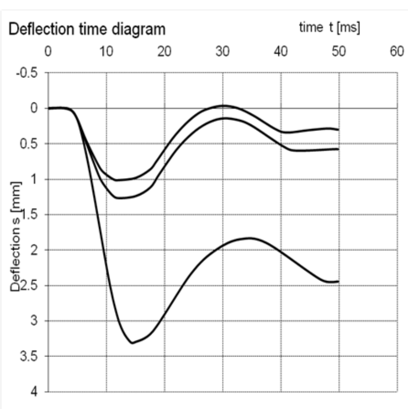
HIA-3



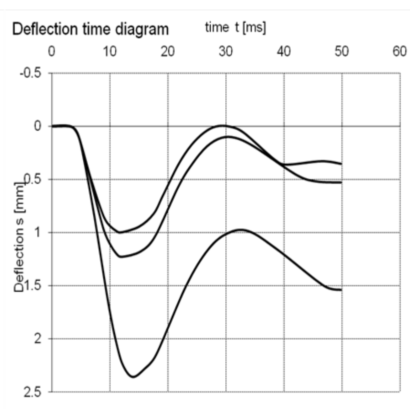
HIA-4



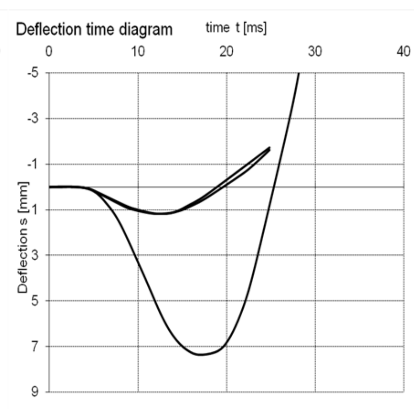
HIA-5



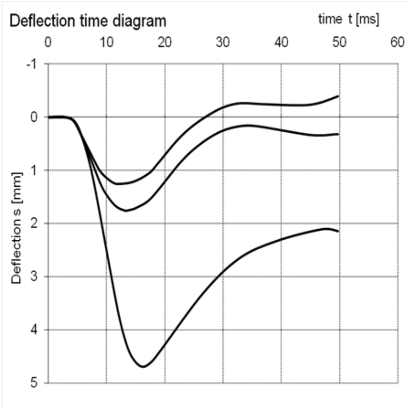
HIA-6 #1



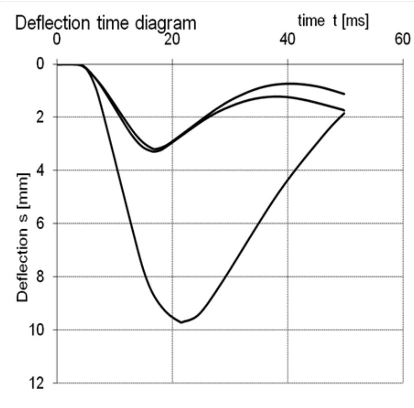
HIA-6 #2



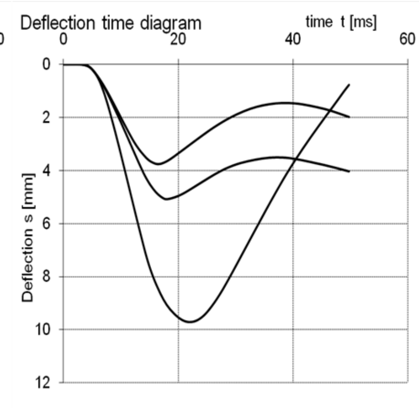
HIA-7 #1



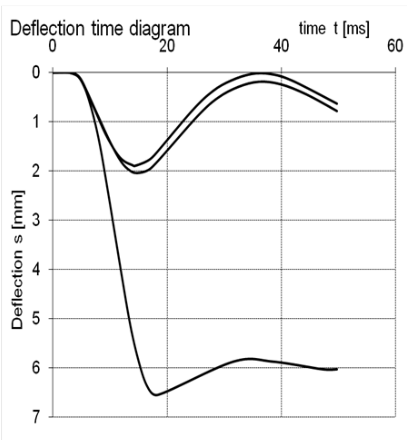
HIA-7 #2



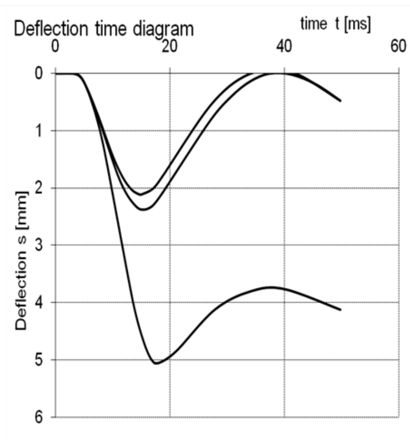
HIA-8 #1



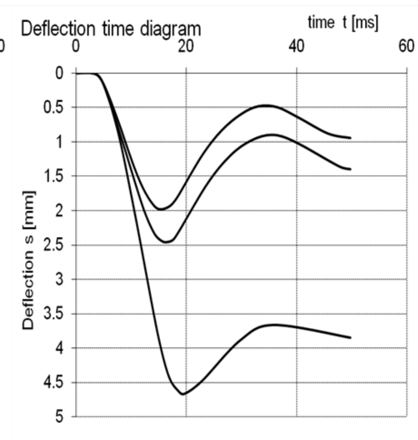
HIA-8 #2



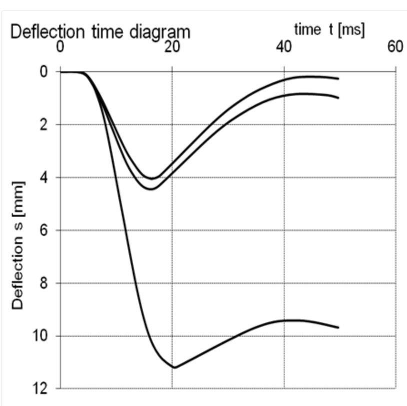
HIA-9



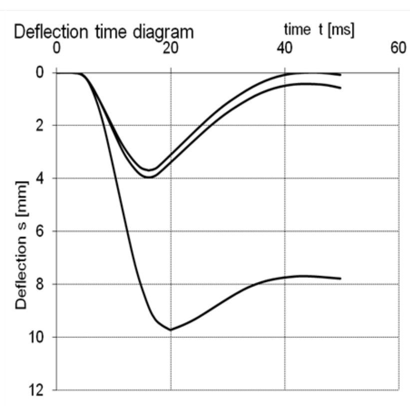
HIA-10



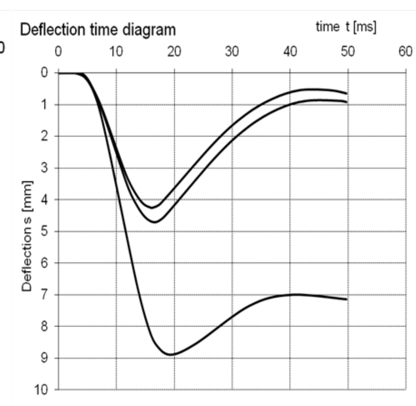
HIA-11



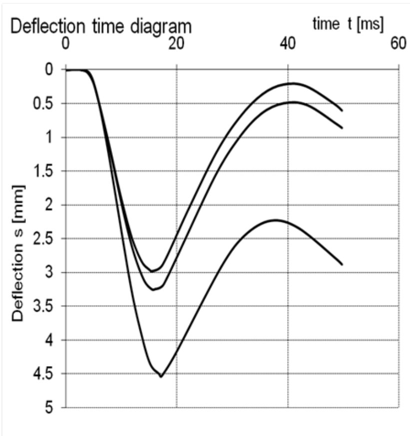
HIA-12 #1



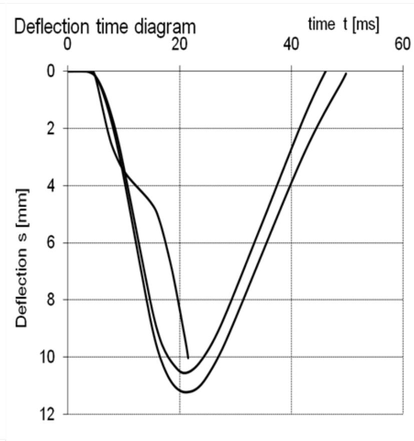
HIA-12 #2



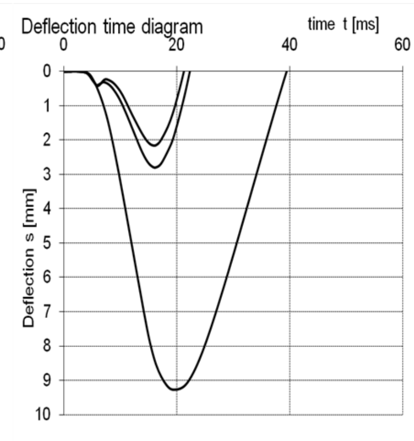
HIA-12 #3



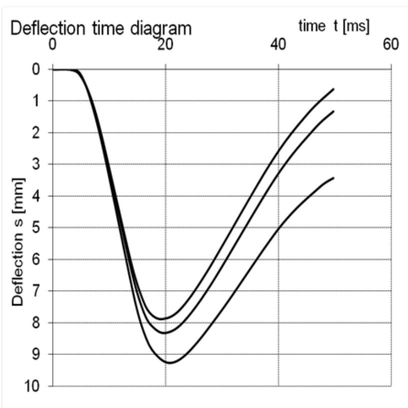
HIA-13



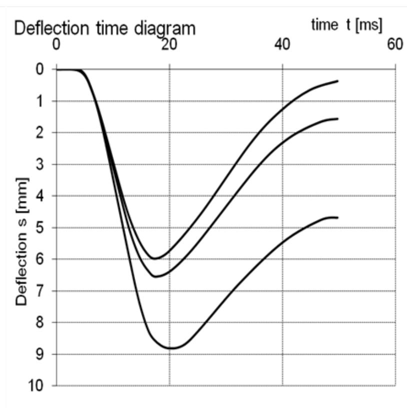
HIA-14 #1



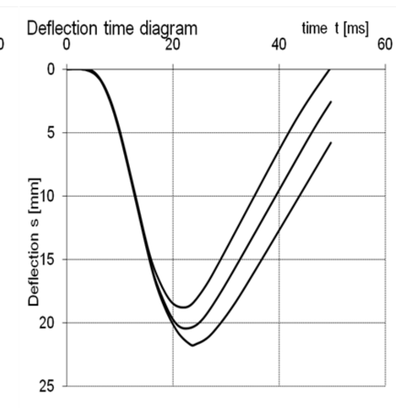
HIA-14 #2



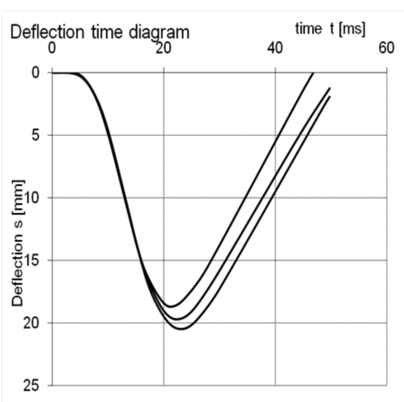
HIA-15



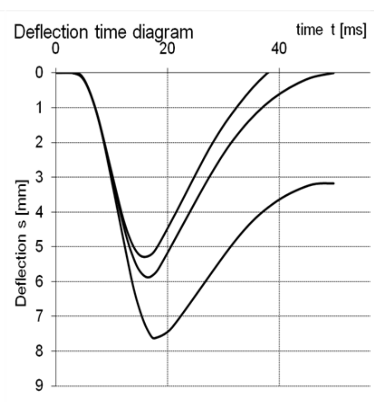
HIA-16



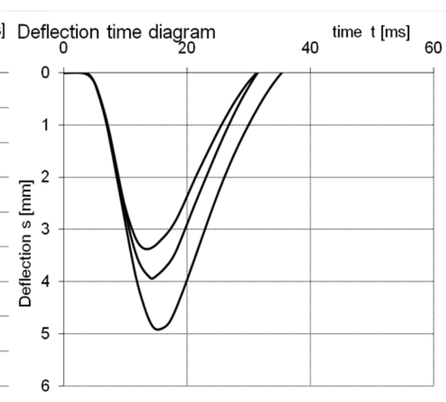
HIA-17 #1



HIA-17 #2

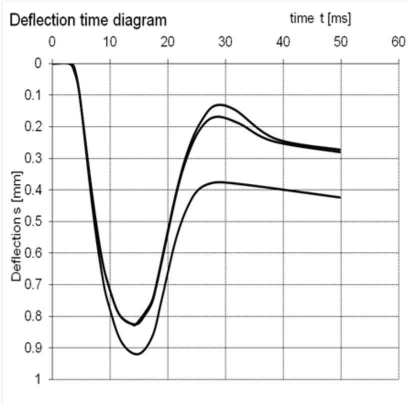


HIA-18

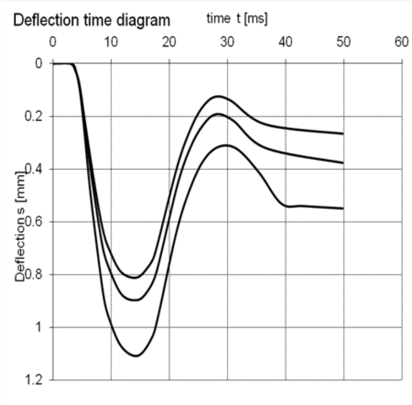


HIA-19

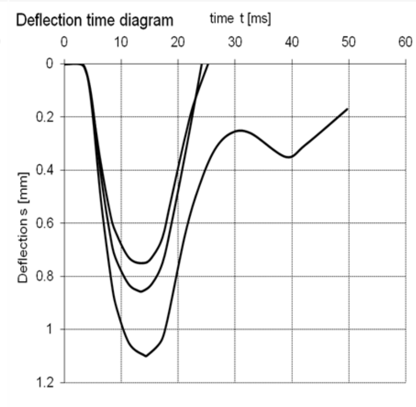
3.8. 7-Sep-2007-Hog Island (HIB) Transect



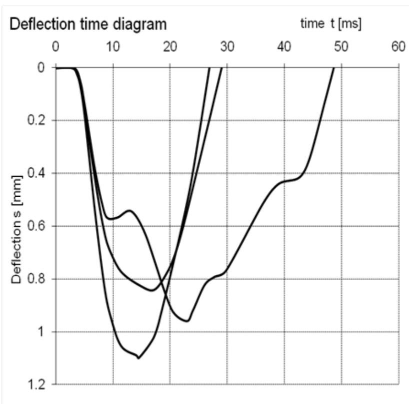
HIB-1



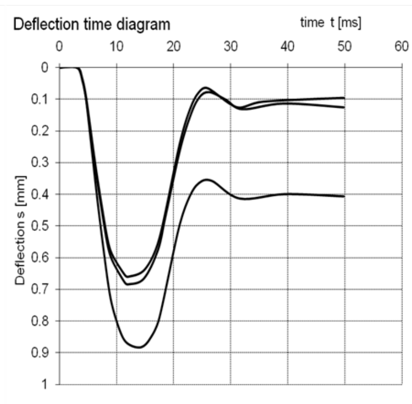
HIB-2



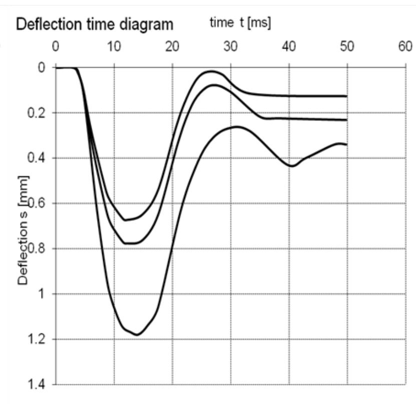
HIB-3 #1



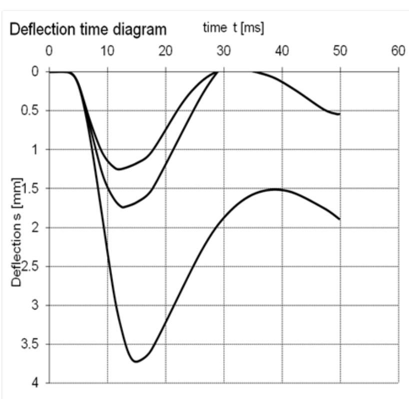
HIB-3 # 2



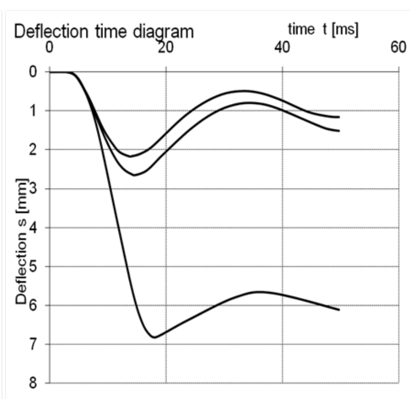
HIB-4



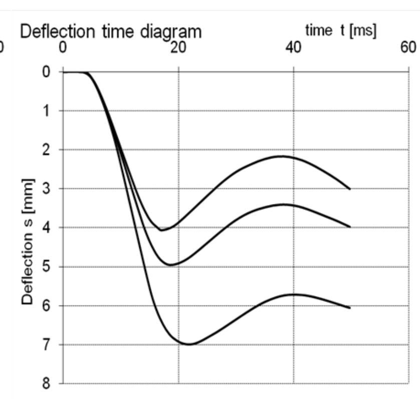
HIB-5



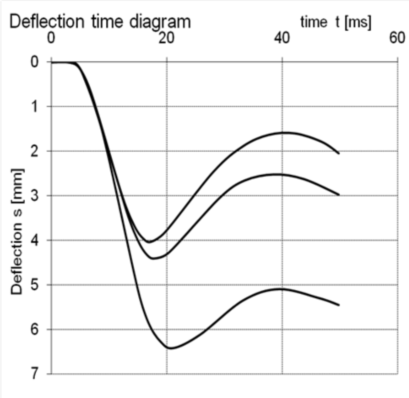
HIB-6



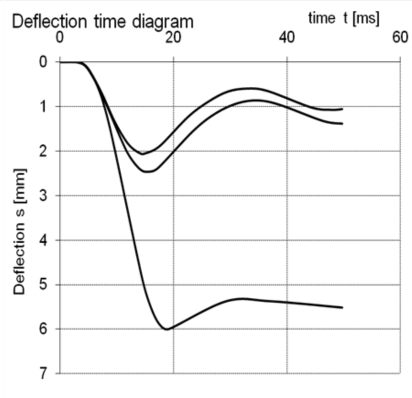
HIB-7



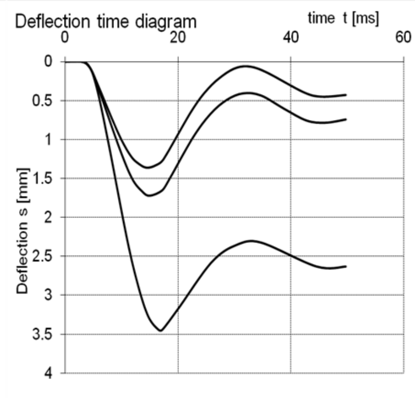
HIB-8 #1



HIB-8 #2

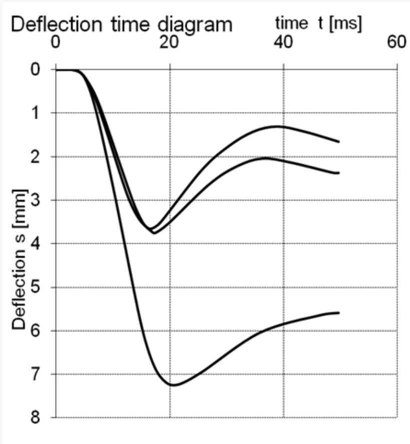


HIB-9

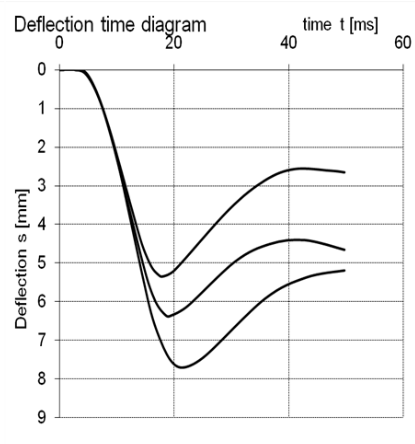


HIB-10

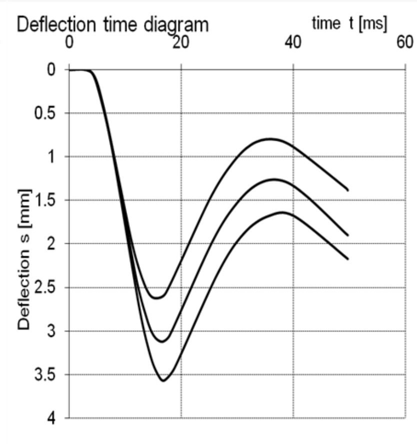
3.9. 8-Sep-2007-Smith Island (NSA) Transect



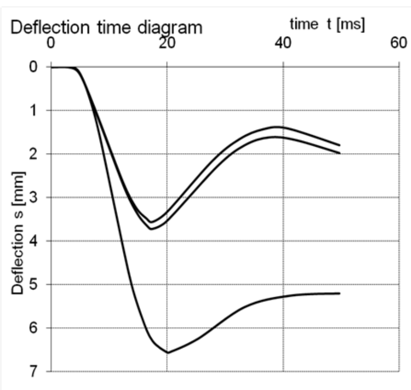
NSA-1



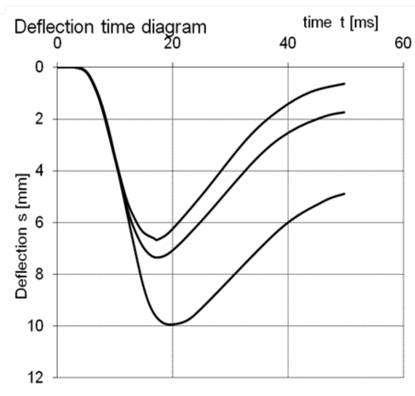
NSA-2



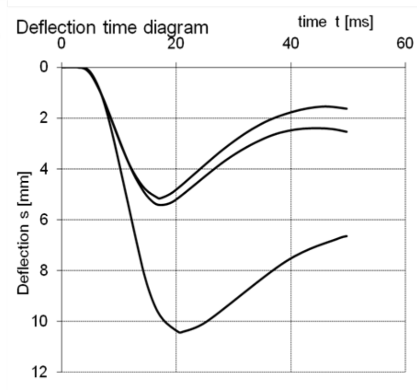
NSA-3



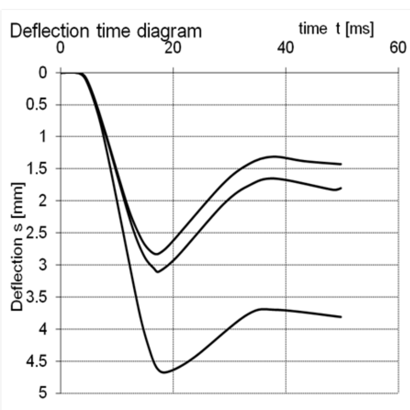
NSA-4



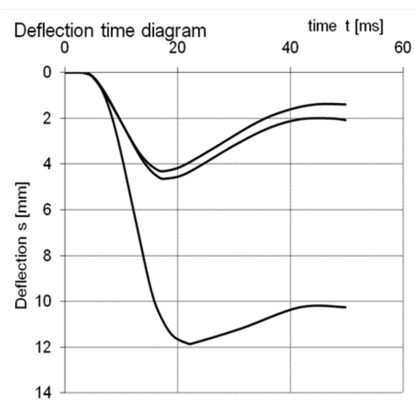
NSA-5



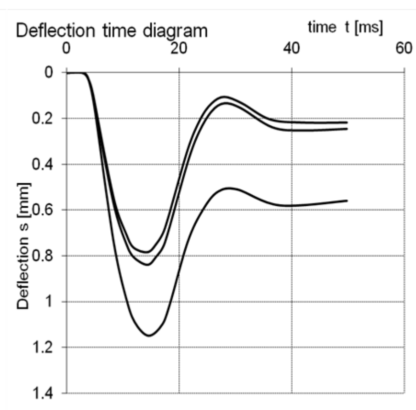
NSA-6



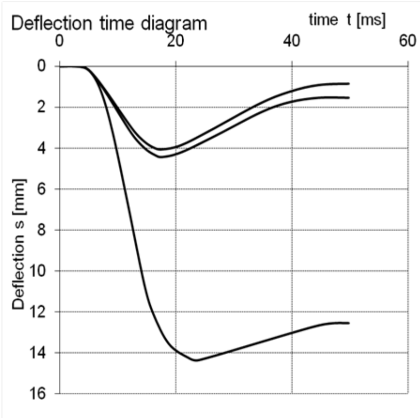
NSA-7



NSA-8

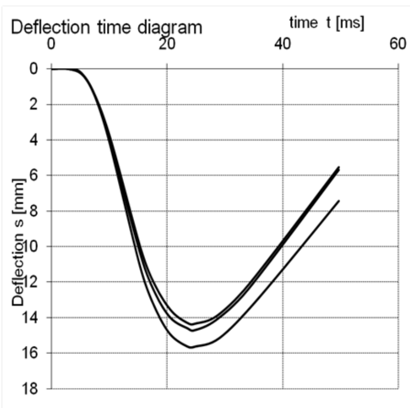


NSA-9

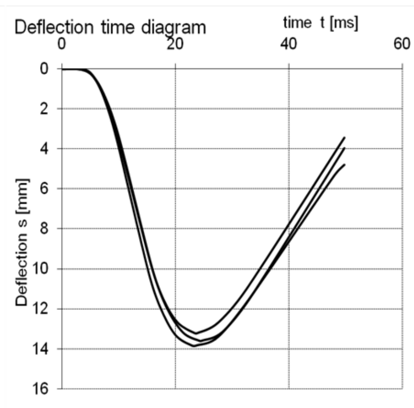


NSA-10

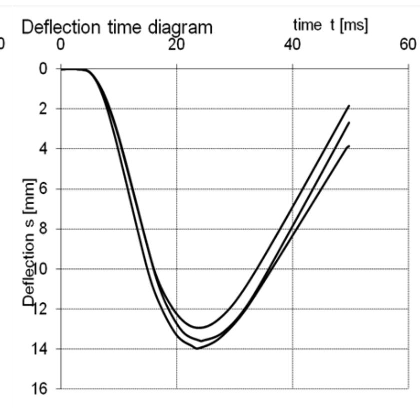
3.10. 8-Sep-2007-Smith Island (NSB) Transect



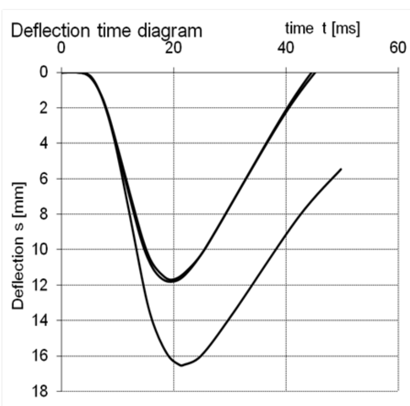
NSB-1



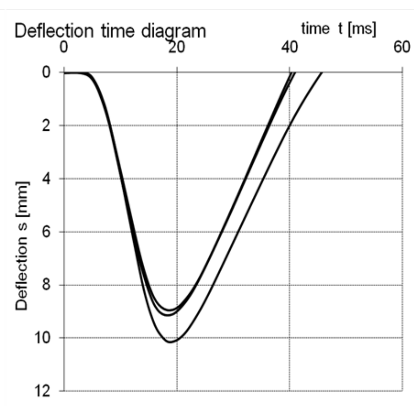
NSB-2



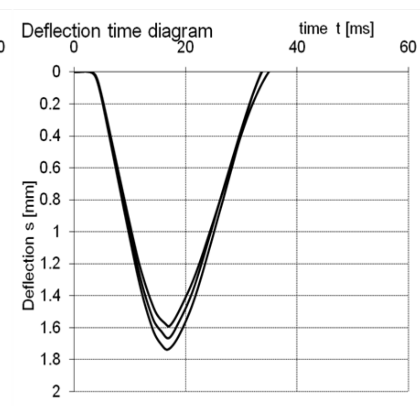
NSB-3



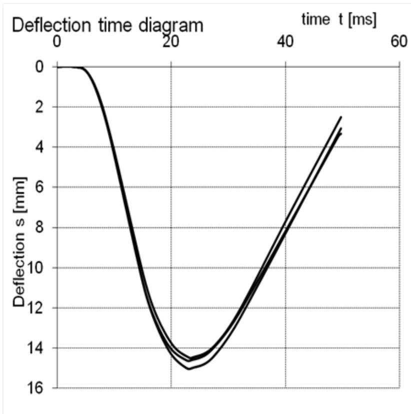
NSB-4



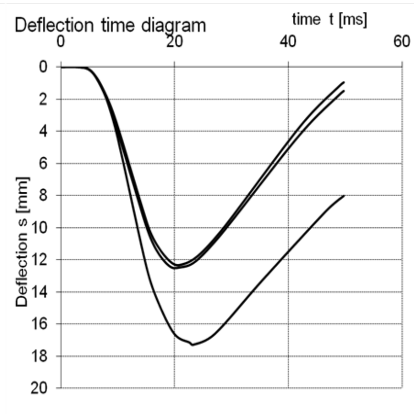
NSB-5



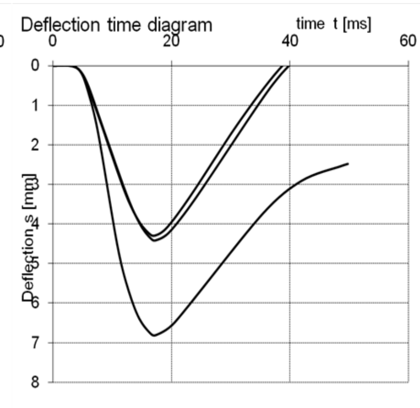
NSB-7



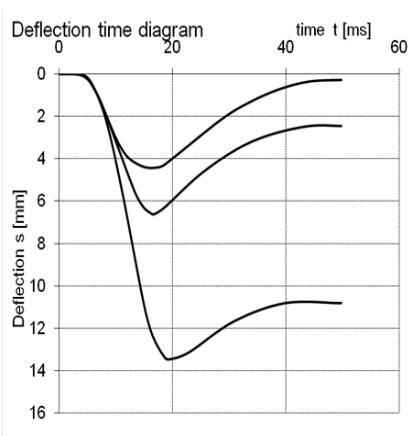
NSB-8



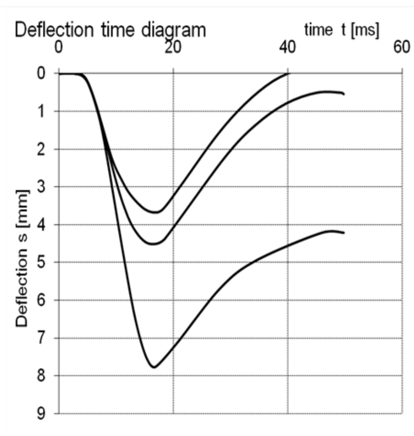
NSB-9



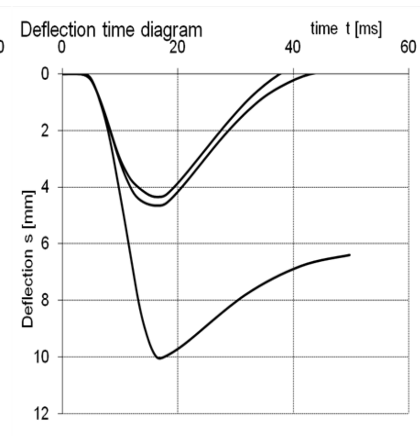
NSB-10



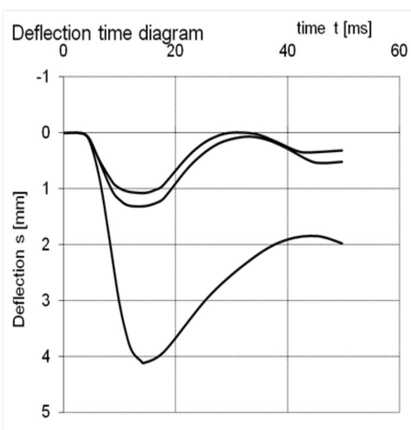
NSB-11 #1



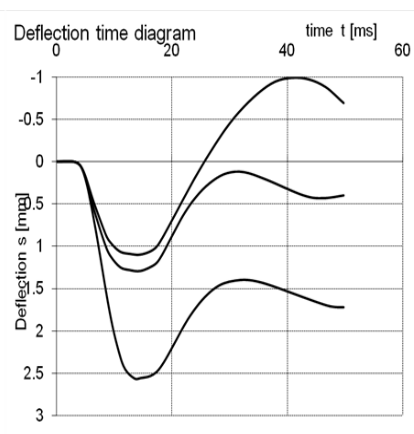
NSB-11 #2



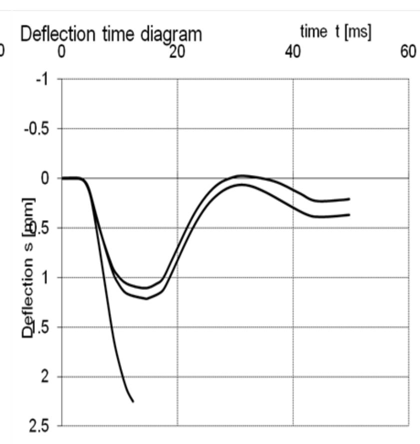
NSB-11 #3



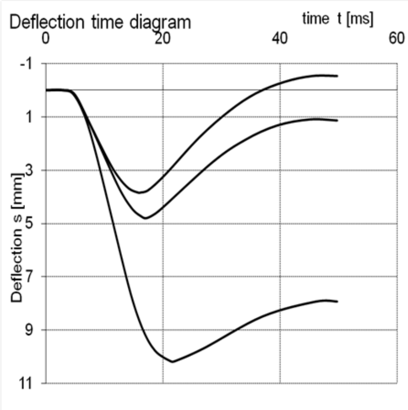
NSB-12 #1



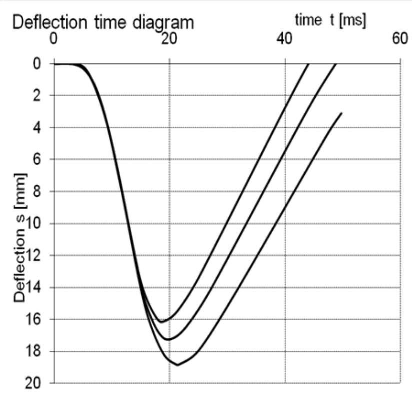
NSB-12 #2



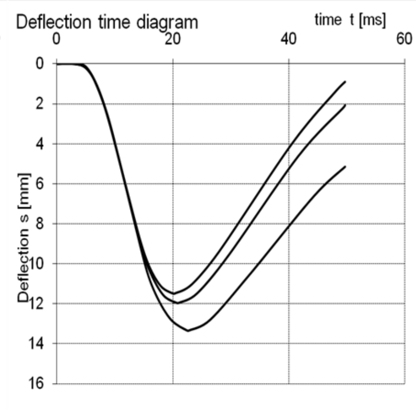
NSB-12 #3



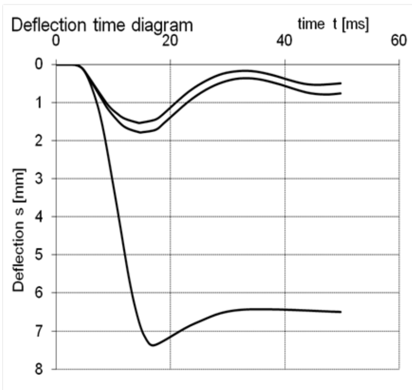
NSB-13



NSB-13 Wrack

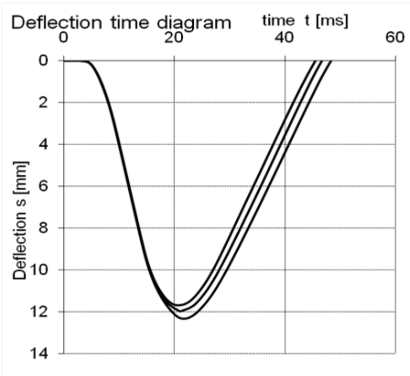


NSB-14

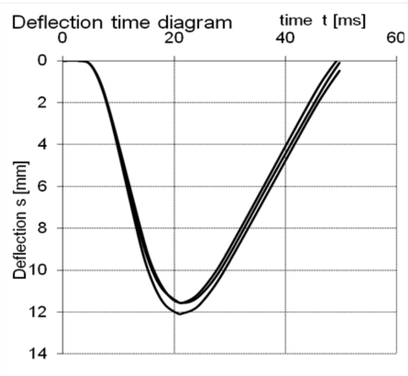


NSB-15

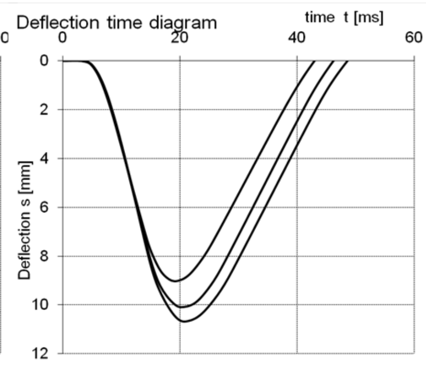
3.11. 10-Sep-2007-Wreck Island (WB) Transect



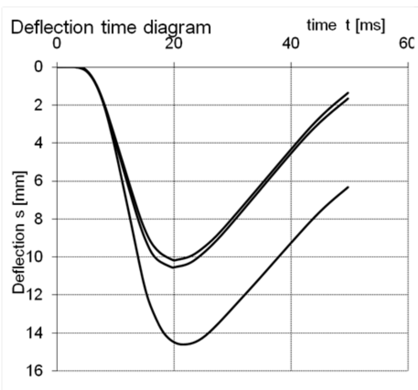
WB-1 #1



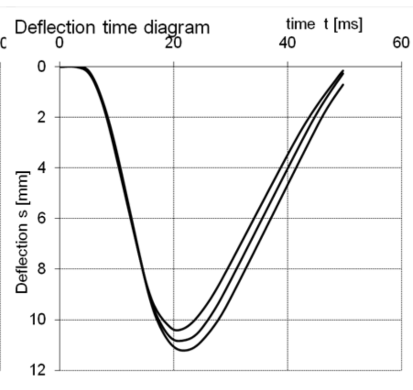
WB-1 #2



WB-2

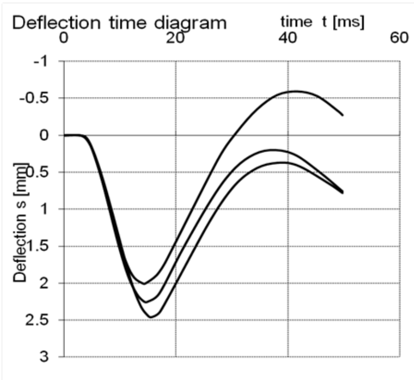


WB-3

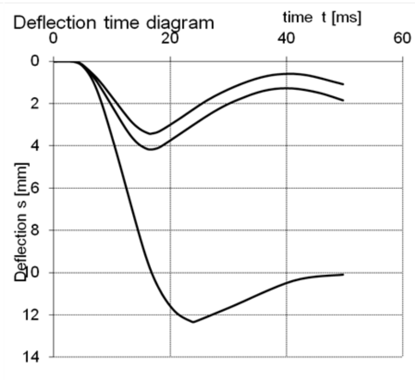


WB-4

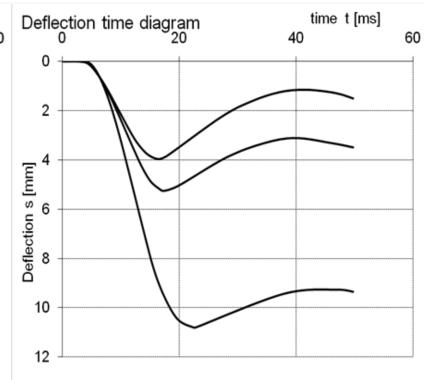
3.12. 12-Sep-2007-Parramore Island (PRD) Transect



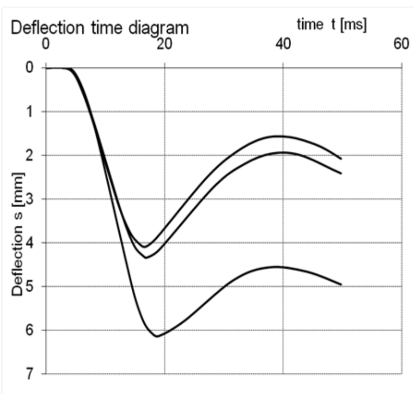
PRD-1



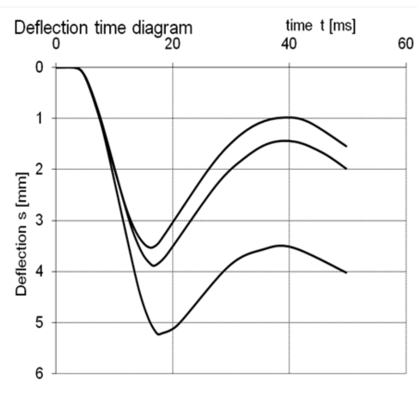
PRD-2 #1



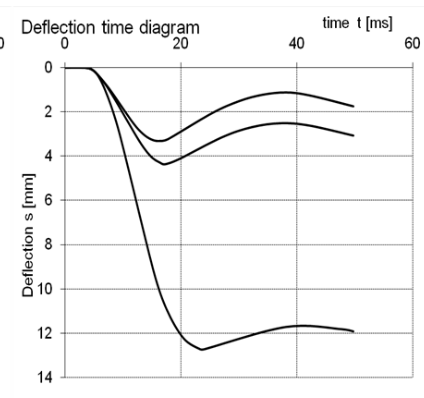
PRD-2 #2



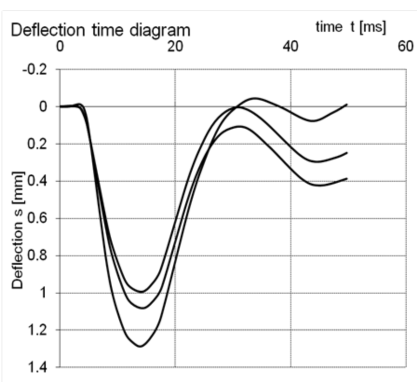
PRD-3 #1



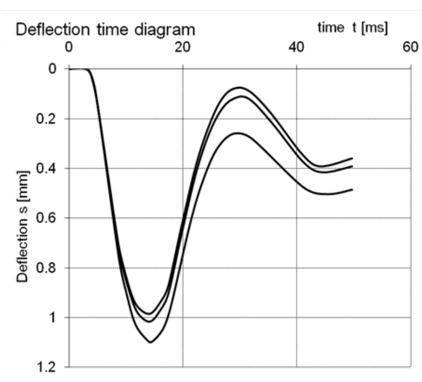
PRD-3 #2



PRD-4

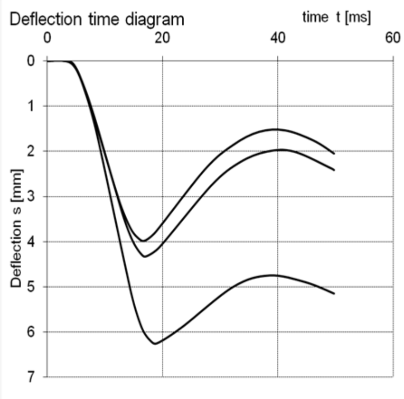


PRD-5

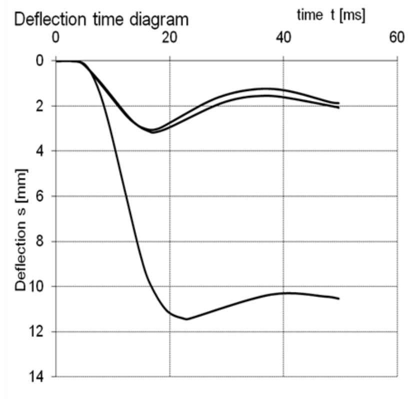


PRD-6

3.13. 12-Sep-2007-Parramore Island (PRE) Transect



PRE-3



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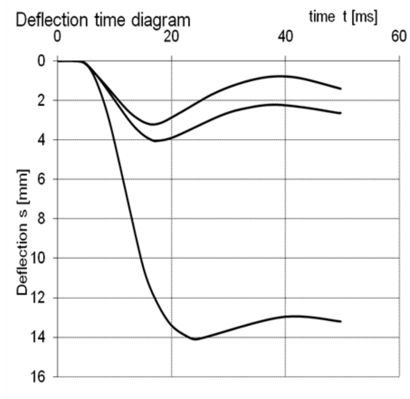
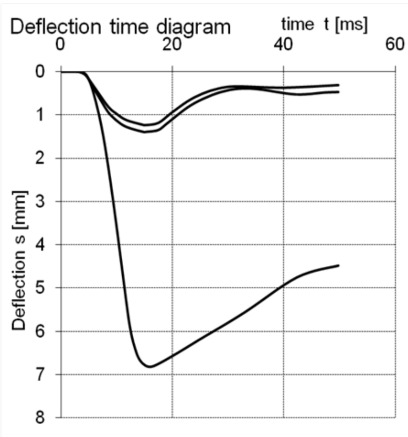
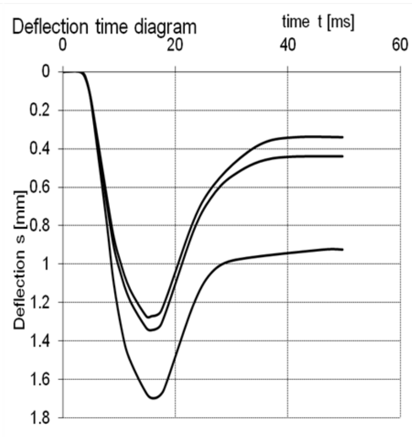


PRE-4 #2

3.14. 13-Sep-2007-Wreck Island (WIC) Transect



WIC-1



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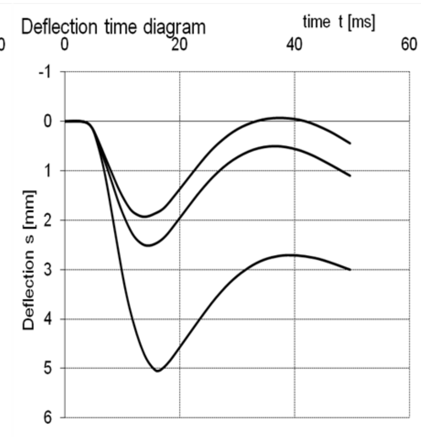

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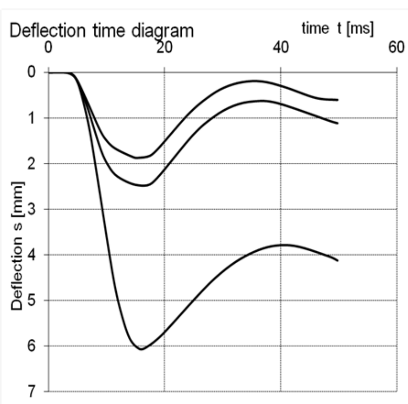
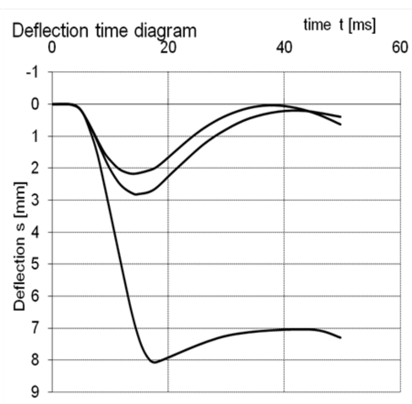


WIC-4



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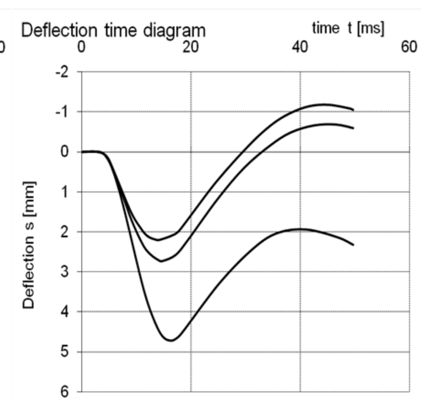
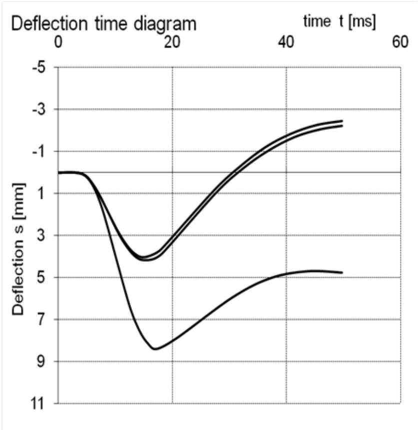
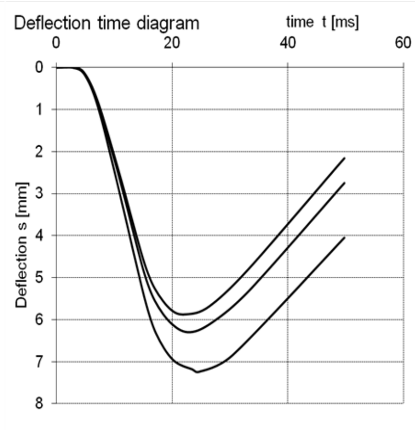


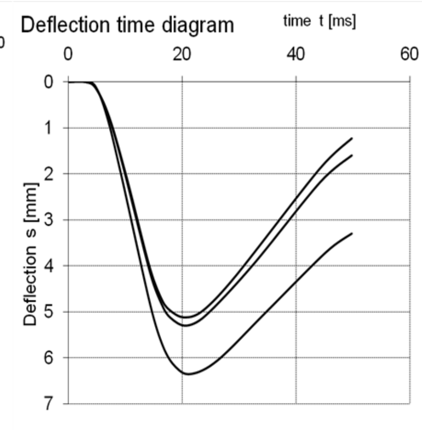
WIC-6



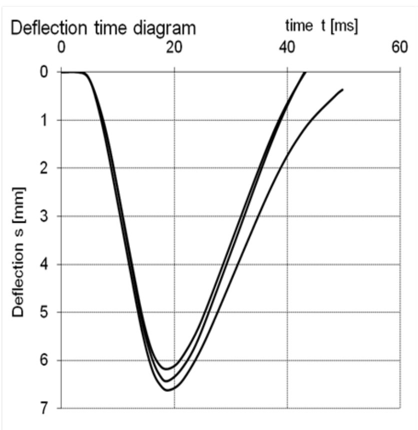
WIC-7



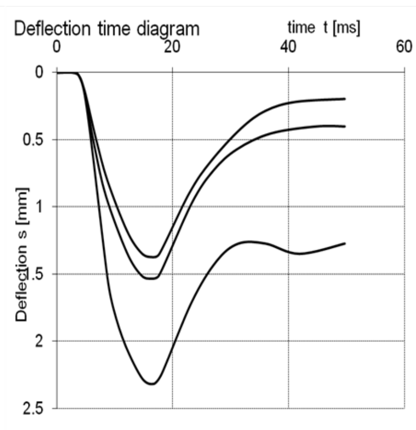
WIC-8



WIC-9



WIC-10



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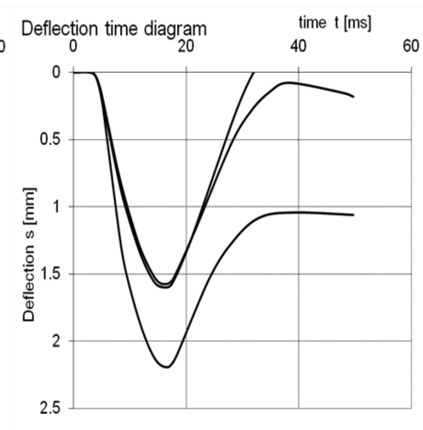
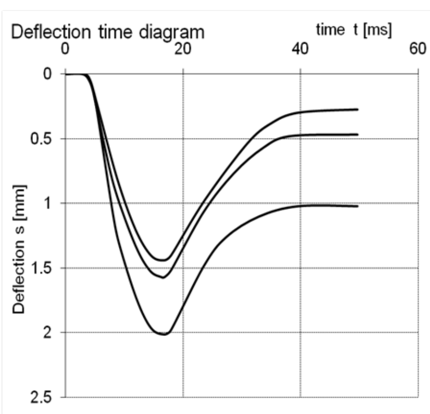
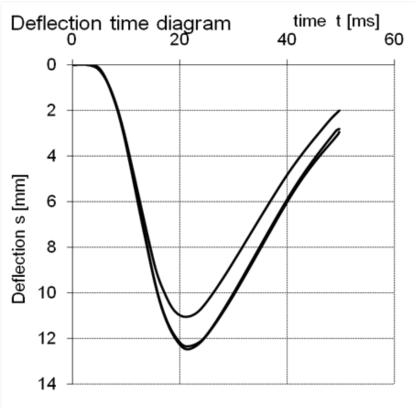


WIC-13

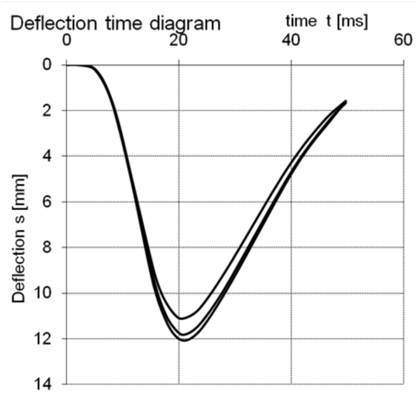


WIC-14

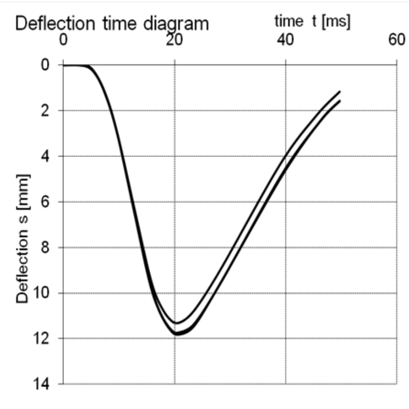
3.15. 16-Sep-2007-Parramore Island (PRF) Transect



PRF-1



PRF-2 #1



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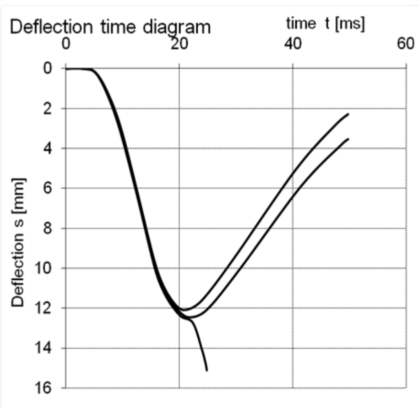

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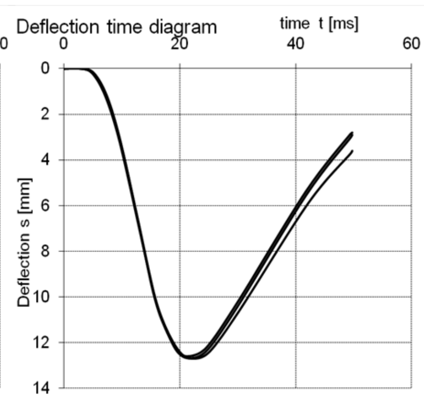
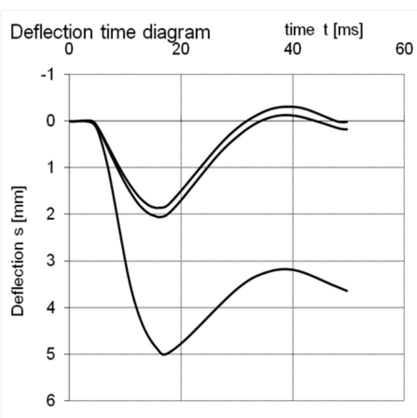
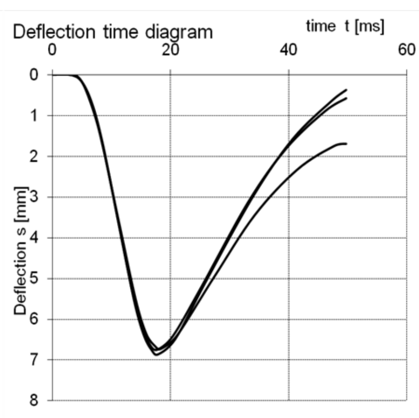


PRF-3 #2

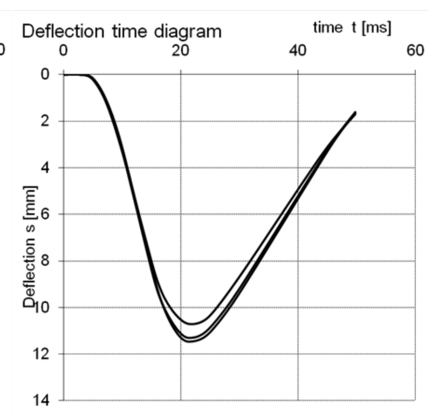
3.16. 16-Sep-2007-Parramore Island (PRG) Transect



PRG-1



PRG-2



PRG-3

APPENDIX G

California Bearing Ratio (CBR)

1. Introduction

California Bearing Ratio (CBR) is used as an empirical measurement of shear strength, one of the two failure mechanisms of soil under load. Combat engineers from Marine Wing Support Squadrons determine soil strength or bearing capacity values for expeditionary airfields before the beginning of aircraft operations. At bases and stations, physical scientists or specially trained civil engineer personnel may conduct these evaluations. In hostile situations, combat engineers attempt to conduct the evaluations under adverse conditions. Basically, the engineers determine strength using a Dynamic Cone Penetrometer (DCP), and then correlate the DCP readings to a CBR value for use in supporting operations.

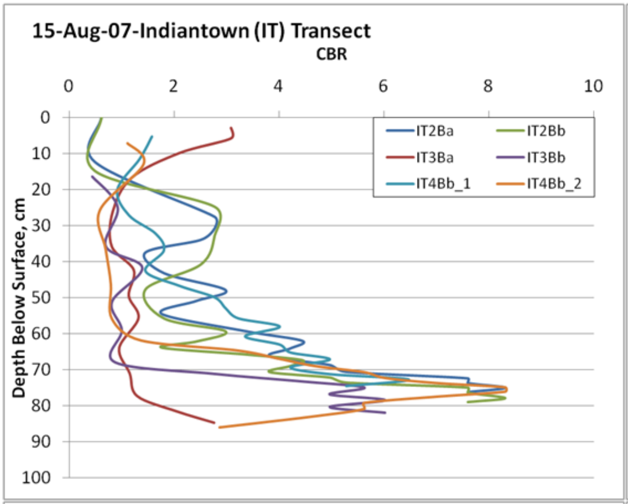
The DCP is the current USMC and USAF standard for measurement of bearing strength for airfields. The use of the DCP is described in ASTM D 6951-03 (American Society for Testing and Materials 2003). The dual-mass DCP consists of a 5/8-in.-diameter steel rod with a steel cone attached to one end, which is driven into the soil by means of a sliding dual-mass hammer. The angle of the cone is 60°, and the diameter of the base of the cone is 0.79 in. For VCR'07, the DCP is driven into the ground by dropping a 10.1-lb sliding hammer from a height of 22.6 in. The depth of cone penetration is measured at selected penetration or hammer-drop intervals and the soil shear strength is reported as the DCP index in millimeters/blow.

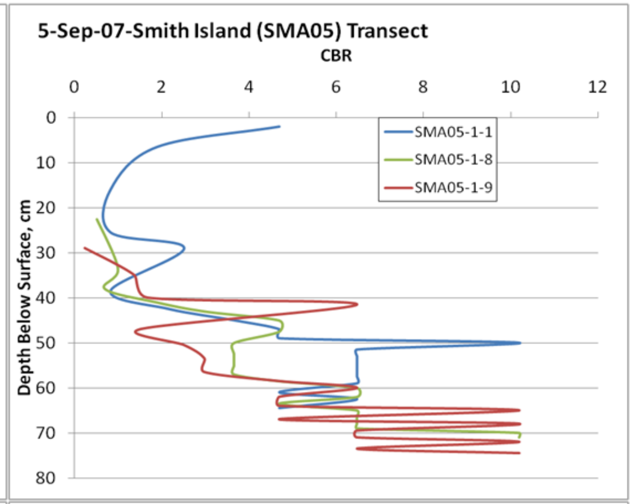
Dynamic Cone Penetrometer test data are recorded in two columns, where the first column is number of blows and the second column is cumulative penetration in mm. In accordance with Army Field Manuals, CBR is computed using the following empirical equations.

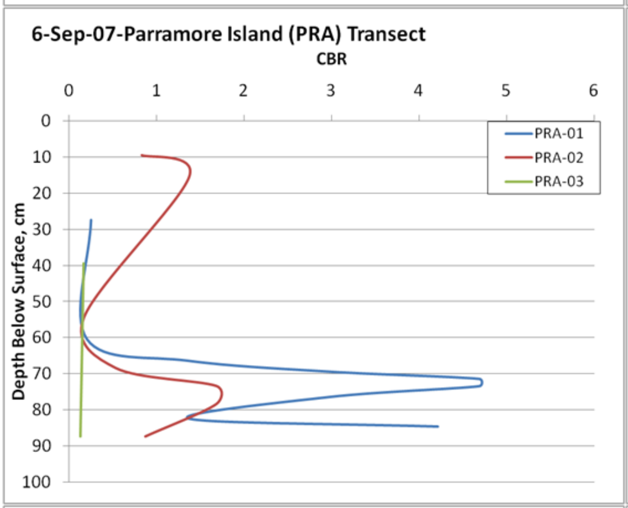
Soils other than CL and CH soils $$CBR = \frac{292}{PR^{1.12}}$$
CL soils: CBR < 10 $$CBR = \frac{1}{(0.017019 \times PR)^2}$$
CH soils $$CBR = \frac{1}{(0.002871 \times PR)}$$
where: • PR is the DCP penetration rate in mm per blow. • CL soils are gravelly clays, sandy clays, silty clays, and lean clays. • CH soils are inorganic clays of high plasticity, including fat clays, gumbo clays, volcanic clays, and bentonite.

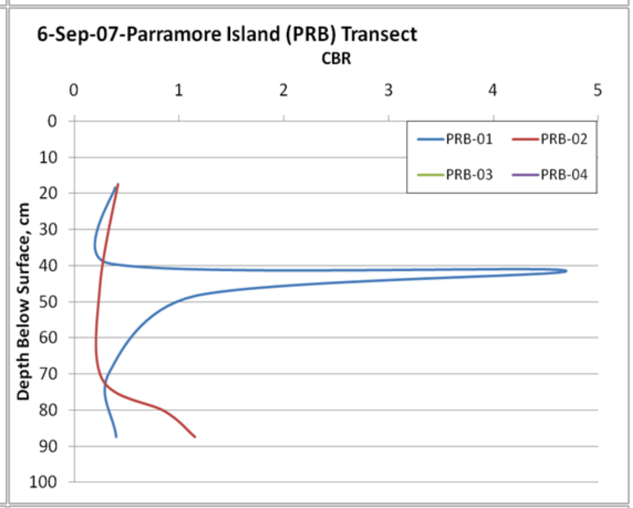
The VCR'07 campaign demonstrates the utility of measuring CBR as a component of littoral penetration point classification and as a trafficability parameter. The CBR was plotted against depth (cm) and can be seen below in the figures for each substrate sample. In the graphs on the following pages, the CBR is plotted on the x-axis and the depth below the surface in centimeters is plotted on the y-axis. Please note the x and y axes' scale changes among the figures.

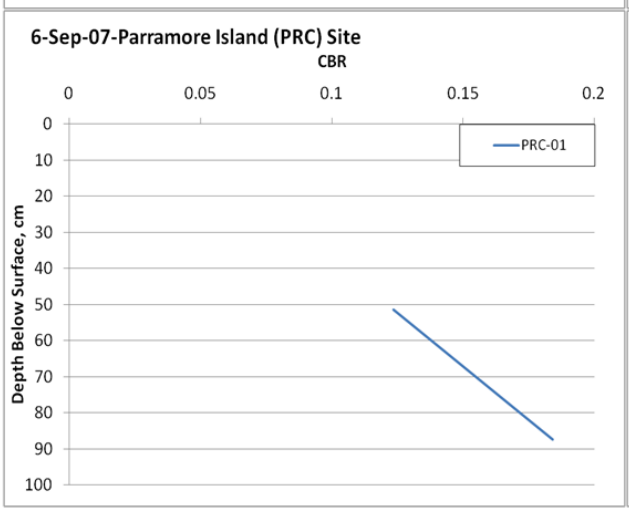
2. California Bearing Ratio Graphs

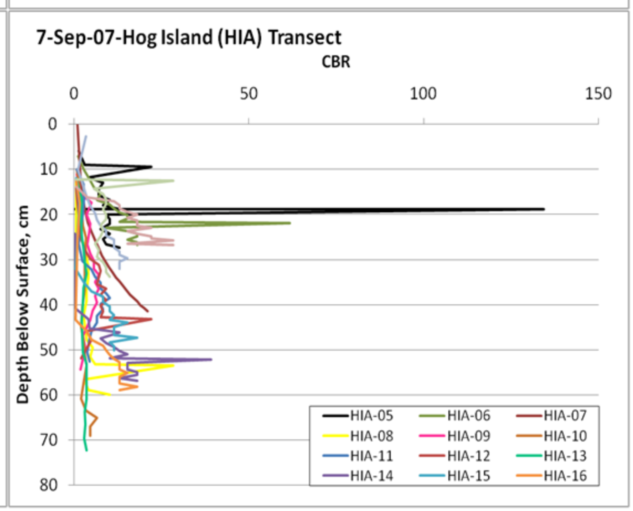


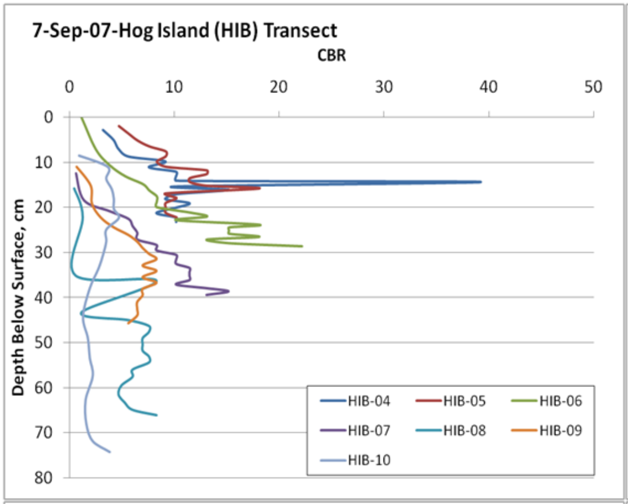


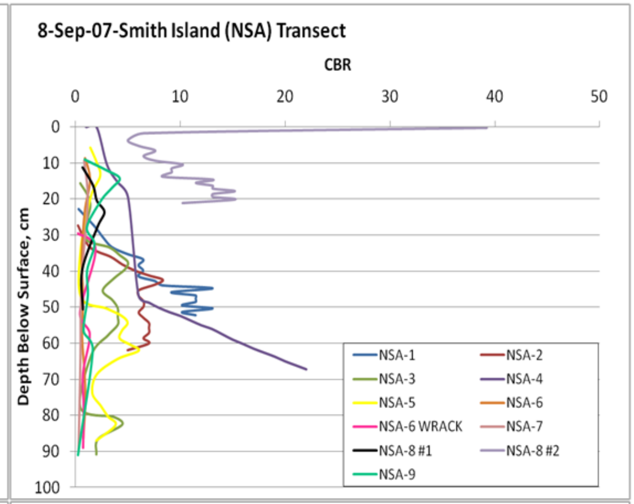


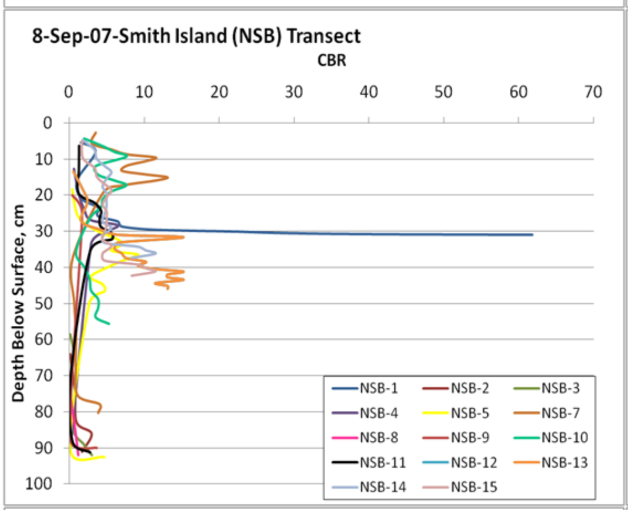


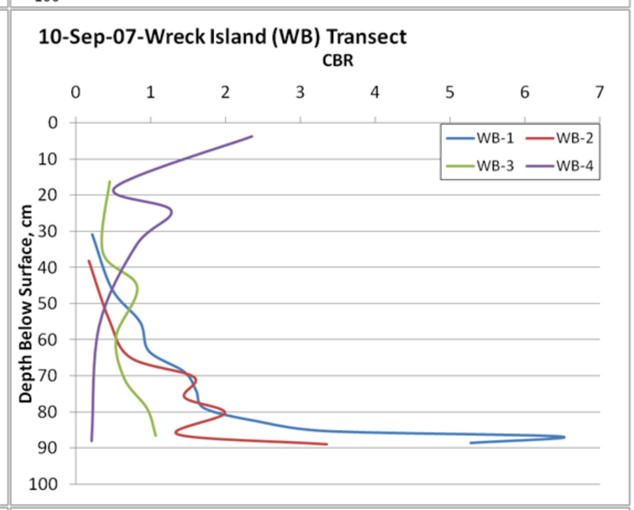


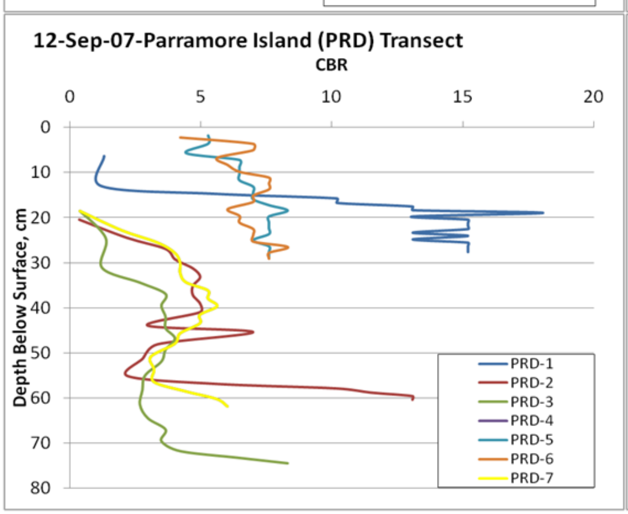


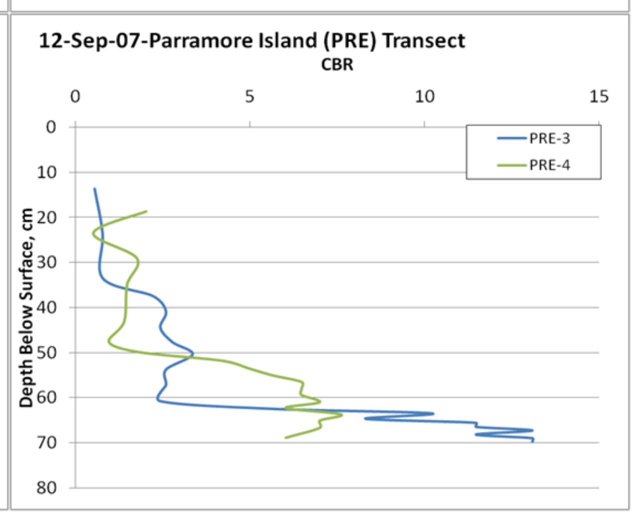

7-Sep-07-Hog Island (HIB) Transect
CBR
0
10
20
30
40
50
Depth Below Surface, cm
0
10
20
30
40
50
60
70
80
HIB-04
HIB-05
HIB-06
HIB-07
HIB-08
HIB-09
HIB-10

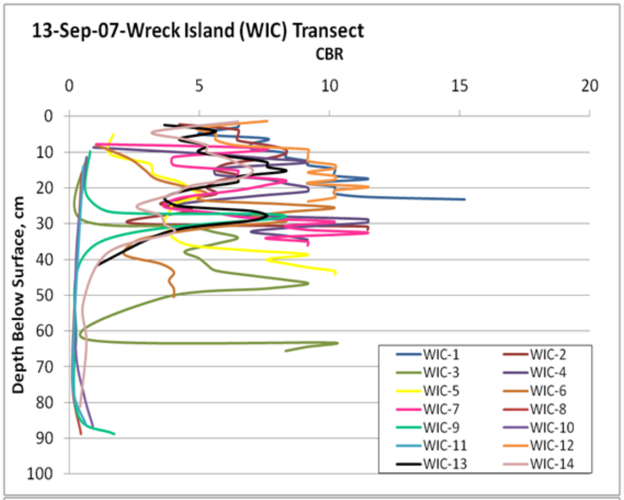

8-Sep-07-Smith Island (NSA) Transect
CBR
0
10
20
30
40
50
Depth Below Surface, cm
0
10
20
30
40
50
60
70
80
90
100
NSA-1
NSA-2
NSA-3
NSA-4
NSA-5
NSA-6
NSA-6 WRACK
NSA-7
NSA-8 #1
NSA-8 #2
NSA-9

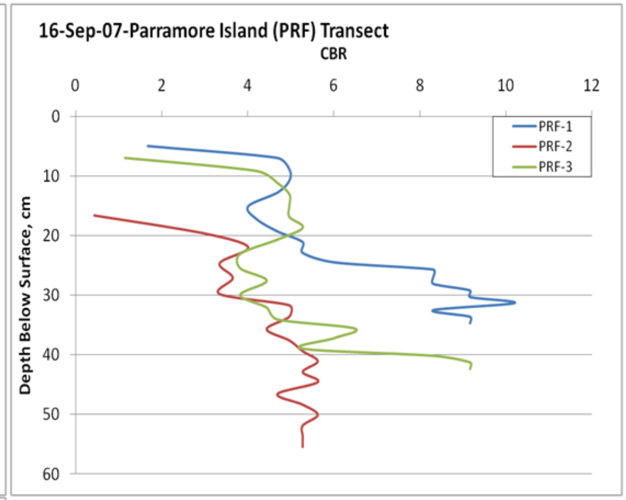

8-Sep-07-Smith Island (NSB) Transect
CBR
0
10
20
30
40
50
60
70
Depth Below Surface, cm
0
10
20
30
40
50
60
70
80
90
100
NSB-1
NSB-2
NSB-3
NSB-4
NSB-5
NSB-7
NSB-8
NSB-9
NSB-10
NSB-11
NSB-12
NSB-13
NSB-14
NSB-15

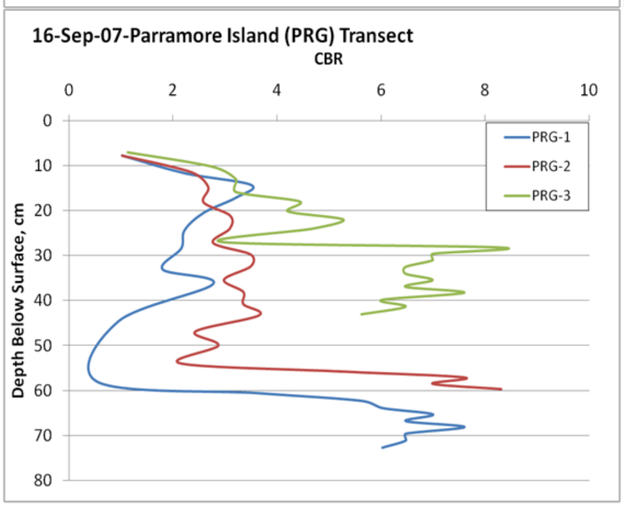

10-Sep-07-Wreck Island (WB) Transect
CBR
0
1
2
3
4
5
6
7
Depth Below Surface, cm
0
10
20
30
40
50
60
70
80
90
100
WB-1
WB-2
WB-3
WB-4


12-Sep-07-Parramore Island (PRD) Transect
CBR
0
5
10
15
20
Depth Below Surface, cm
0
10
20
30
40
50
60
70
80
PRD-1
PRD-2
PRD-3
PRD-4
PRD-5
PRD-6
PRD-7


12-Sep-07-Parramore Island (PRE) Transect
CBR
0
5
10
15
Depth Below Surface, cm
0
10
20
30
40
50
60
70
80
PRE-3
PRE-4


13-Sep-07-Wreck Island (WIC) Transect
CBR
0
5
10
15
20
Depth Below Surface, cm
0
10
20
30
40
50
60
70
80
90
100
WIC-1
WIC-2
WIC-3
WIC-4
WIC-5
WIC-6
WIC-7
WIC-8
WIC-9
WIC-10
WIC-11
WIC-12
WIC-13
WIC-14


16-Sep-07-Parramore Island (PRF) Transect
CBR
0
2
4
6
8
10
12
Depth Below Surface, cm
0
10
20
30
40
50
60
PRF-1
PRF-2
PRF-3


16-Sep-07-Parramore Island (PRG) Transect
CBR
0
2
4
6
8
10
Depth Below Surface, cm
0
10
20
30
40
50
60
70
80
PRG-1
PRG-2
PRG-3

APPENDIX H

Other Soil Properties

1. Introduction

Determining beach composition was an essential VCR'07 task involving the collection of "grab samples" across the beach and marshland. Two of four standard soil tests were accomplished; (1) moisture content determinations and (2) grading or sieve analysis. Soil samples were collected with a corer to a critical depth of 3 inches (7.62cm). Samples are collected as quickly as possible and stored in either zip-loc bags or sediment corer tubes, to prevent the loss of moisture to evaporation. When possible, samples were placed in a cooler to keep the samples at a moderate temperature. Samples were then taken to the lab to determine soil moisture and grain size distributions.

After soil samples were taken to the lab, quick and careful procedures were taken to determine soil moisture. The moisture content is expressed as a percentage and is the mass of wet soil divided by the dry mass of soil times one hundred. The soil moisture is determined by a similar protocol found in the Army Field Manual for materials testing (FM 5-472, NAVFAC MO 330,AFJMAN 32-1221(I)) which follows the microwave oven method for determining soil moisture content (ASTM D 4643-87). After soil moisture was determined, soil grain size determination commenced. Soil grain size determination followed the procedures set by the Army Field Manual mentioned above with the mechanical (sieve analysis) method being implemented. The industry standard testing soil particle size of soils (ASTM D 422-63) requires a two step process in which a sedimentation process (hyrdrometer analysis) is used to analyze soil grains smaller than sieve No. 200, but FM 5-472 indicates adequate analysis will be accomplished without the use of the sedimentation process.

Soil moisture and soil grain size distribution data can be seen below in Sections 4 and 5, respectively. In Section 6, soil grain size distribution graphs are displayed. The graphs have the percent of sample listed on the y-axis while the sieve size is listed along the x-axis.

2. Soil Moisture Determination

The technique of soil drying by oven is one of the most widely used gravimetric methods for measuring soil moisture and is the calibration of all other soil moisture determination techniques(Schmugge, 1980).

2.1. Preparing the Soil Sample

The following protocol discusses the methodology for soil moisture content determination which was undertaken at the ABCRC.

1. We opened windows to ensure good ventilation because of fumes from microwave baking of soil samples.
2. The weighing container was weighed prior to putting soil on the container. This value is needed for the calculation of soil moisture.
3. Approximately 25 grams of wet/moist soil was placed on the container and the weight of soil and container is measured.
4. Drying the sample was done with a microwave oven. The microwave oven is faster for drying then using a field moisture oven. The appropriate steps for drying with a microwave oven are seen below.

2.2. Soil Sample Drying in a Microwave Oven

The following lists the protocol taken in order to dry a soil sample in a microwave oven:

1. Place sample into microwave with a heat sink (brick) and run the microwave oven for 6 minutes.
2. Weigh the sample and return to microwave oven for 1 minute and reweigh. If the weight of the sample has changed, return to the microwave oven for 1 more minute.
3. Repeat the process until a constant weight is achieved.
4. Record the following measurements
    - (net weight) - (weight of container) = net soil weight
    - (dry weight) - (weight of container) = dry soil weight
    - (net soil weight) - (dry soil weight) = water weight
    - (water weight) ÷ (dry soil weight) = soil water content

(Typical drying times for a wet sample are less than 20 minutes. Water is the first component of the soil to heat and evaporate. If the sample is dry and microwave drying continues, the soil temperature will increase and oxidize organic matter. This is to be avoided as it would bias results.)

2.3. Soil Moisture Content Equations

The soil's moisture content (in percent) is calculated as the ratio of the mass of the water contained in the soil to the mass of the dry soil and multiplied by 100 (Black, 1965, Famiiglietti, 1998). The soil's moisture content (also referred to as water content) is an indicator of the amount of water present in a soil. By definition, moisture content is the ratio of the weight of water in a sample to the weight of solids (oven-dried) in the sample, expressed as a percentage (w). The equation can be seen in the box below.

Soil Moisture Content Equation

$$w = \frac{W_w}{W_s} \times 100$$

Where:

w= moisture content of the soil (expressed as a percentage)

W_w = weight of water in the soil sample

W_s = weight of oven-dried-soil solids in the sample

3. Grain Size Distributions

After soil moisture is determined, samples are graded using a stack of appropriately sized sieves. For civil engineering applications, a certain series of sizes has come to be standard. Those most commonly used to grade materials have openings varying from 125mm down to 0.075mm and are stacked one on top of the other; in our experiments we added sieves for particles as small as 0.027 mm (27 microns) (Tests are often described by identifying sieve sizes by their opening in millimeters followed by English aperture size: for example, 4.75mm (No. 4) sieve. All sieves have square openings.) For beach composition, the grading analysis is the most important of all the soil tests, since factors such as beach gradient can be estimated from grain size. In order to grade the sample properly, the sieving operation uses a mechanical shaker to obtain lateral, vertical, and jarring actions, which keep the sample moving continuously over the surface of the sieve. After sufficient shaking, the mass of each sieve size is determined on a scale or balance. Then, the total percentage of material passing each sieve is calculated. Percentages are calculated to the nearest whole number except for the amount of material finer than the 0.075mm (No. 200) sieve, which is reported to the nearest 0.1 percent. If the total amount of material finer than 0.075 mm (No. 200) sieve is desired, it is determined by adding the mass of material passing the 0.075mm (No. 200) sieve by dry sieving.

4. Soil Moisture Content Data

Locality Index: HI= Hog Island; PI=Parramore Island; SI= Smith Island; WI= Wreck Island.

Sample_Name	Sample-Date	Locality	Sample Wet Weight (g)	Sample Dry Weight (g)	Soil Moisture Content (*w*) %
SMA05-1-2	05-Sep-07	SI	271.4	202.7	34
SMA05-1-2	05-Sep-07	SI	298.7	217.1	38
SMA05-1-8	05-Sep-07	SI	455.9	302.9	51
SMA05-1-9	05-Sep-07	SI	327.6	221.1	48
PRA-1	06-Sep-07	PI	292.2	166.9	75
PRA-2	06-Sep-07	PI	235.3	134.3	75
PRA-3	06-Sep-07	PI	326.6	190.4	72
PRB-1	06-Sep-07	PI	498.2	325.4	53
PRB-2	06-Sep-07	PI	543.0	377.3	44
PRB-3	06-Sep-07	PI	423.8	247.1	72
PRB-4	06-Sep-07	PI	486.7	299.3	63
PRB-4 (Veg on)	06-Sep-07	PI	541.8	320.4	69
PRC-1	06-Sep-07	PI	447.0	261.6	71
PRS (LWD)	06-Sep-07	PI	355.7	207.4	72
HIA-1	07-Sep-07	HI	243.0	201.9	20
HIA-2	07-Sep-07	HI	196.1	162.4	21
HIA-3	07-Sep-07	HI	541.2	446.3	21
HIA-4	07-Sep-07	HI	222.2	183.4	21
HIA-5	07-Sep-07	HI	330.0	276.0	20
HIA-6	07-Sep-07	HI	275.2	255.2	8
HIA-7	07-Sep-07	HI	248.8	237.2	5
HIA-8	07-Sep-07	HI	244.1	239.0	2
HIA-10	07-Sep-07	HI	268.4	266.4	1
HIA-11	07-Sep-07	HI	410.0	407.8	1
HIA-12	07-Sep-07	HI	239.9	238.8	0
HIA-13	07-Sep-07	HI	176.0	174.2	1
HIA-14	07-Sep-07	HI	192.2	155.8	23
HIA-15	07-Sep-07	HI	211.4	178.4	18
HIA-16	07-Sep-07	HI	199.8	179.8	11
HIA-17	07-Sep-07	HI	286.7	230.8	24
HIA-18	07-Sep-07	HI	264.4	218.4	21
HIA-19	07-Sep-07	HI	206.8	165.3	25
HIB-1	07-Sep-07	HI	190.0	157.0	21
HIB-2	07-Sep-07	HI	198.5	164.8	20
HIB-3	07-Sep-07	HI	209.1	171.7	22
HIB-4	07-Sep-07	HI	225.8	187.8	20
HIB-5	07-Sep-07	HI	218.0	187.1	17
HIB-6	07-Sep-07	HI	159.2	149.7	6
HIB-7	07-Sep-07	HI	249.1	236.8	5
HIB-8	07-Sep-07	HI	208.9	205.1	2
HIB-9	07-Sep-07	HI	228.0	224.0	2
HIB-10	07-Sep-07	HI	197.6	193.9	2

Sample_Name	Sample-Date	Locality	Sample Wet Weight (g)	Sample Dry Weight (g)	Soil Moisture Content (*w*) %
NSA-1	08-Sep-07	SI	190.0	175.4	8
NSA-2	08-Sep-07	SI	169.4	161.6	5
NSA-3	08-Sep-07	SI	183.8	182.0	1
NSA-4	08-Sep-07	SI	184.5	181.3	2
NSA-5	08-Sep-07	SI	137.0	134.3	2
NSA-6	08-Sep-07	SI	126.3	118.5	7
NSA-7	08-Sep-07	SI	221.7	220.1	1
NSA-8	08-Sep-07	SI	126.0	119.3	6
NSA-9	08-Sep-07	SI	250.4	206.6	21
NSA-10	08-Sep-07	SI	178.7	166.8	7
NSA-11	08-Sep-07	SI	210.8	181.6	16
NSB-1	08-Sep-07	SI	247.1	164.0	51
NSB-2	08-Sep-07	SI	213.2	135.4	57
NSB-3	08-Sep-07	SI	217.4	146.5	48
NSB-4	08-Sep-07	SI	226.1	158.4	43
NSB-5	08-Sep-07	SI	186.8	146.8	27
NSB-7	08-Sep-07	SI	212.7	174.4	22
NSB-8	08-Sep-07	SI	199.4	140.8	42
NSB-9	08-Sep-07	SI	261.7	170.3	54
NSB-10	08-Sep-07	SI	205.1	167.2	23
NSB-11	08-Sep-07	SI	202.2	173.2	17
NSB-13	08-Sep-07	SI	180.4	172.1	5
NSB-14	08-Sep-07	SI	140.9	130.2	8
NSB-15	08-Sep-07	SI	153.8	145.4	6
WB-1	10-Sep-07	WI	217.2	128.2	69
WB-2	10-Sep-07	WI	196	111.7	75
WB-3	10-Sep-07	WI	246.4	151.1	63
WB-4	10-Sep-07	WI	223.5	140.8	59
PRD01	12-Sep-07	PI	594.5	496.1	20
PRD02	12-Sep-07	PI	573.9	526.0	9
PRD03	12-Sep-07	PI	522.9	504.7	4
PRD04	12-Sep-07	PI	196.7	193.9	1
PRD05	12-Sep-07	PI	379.8	312.5	22
PRD06	12-Sep-07	PI	413.9	340.7	21
PRE03	12-Sep-07	PI	148.1	143.3	3
PRE04	12-Sep-07	PI	274.3	267.3	3
PRASWB	12-Sep-07	PI	275.0	186.7	47

Sample_Name	Sample-Date	Locality	Sample Wet Weight (g)	Sample Dry Weight (g)	Soil Moisture Content (*w*) %
WIC-1	13-Sep-07	WI	180.3	147.2	22
WIC-2	13-Sep-07	WI	238.1	190.9	25
WIC-3	13-Sep-07	WI	177.6	165.6	7
WIC-4	13-Sep-07	WI	136.5	126.5	8
WIC-5	13-Sep-07	WI	191.2	188.1	2
WIC-6	13-Sep-07	WI	193.5	191.2	1
WIC-7	13-Sep-07	WI	225.1	223.9	1
WIC-8	13-Sep-07	WI	262.4	214.2	23
WIC-9	13-Sep-07	WI	232.2	198.1	17
WIC-10	13-Sep-07	WI	230.3	190.3	21
WIC-11	13-Sep-07	WI	234.4	185.6	26
WIC-12	13-Sep-07	WI	269.7	226.3	19
WIC-13	13-Sep-07	WI	226.8	182.1	25
WIC-14	13-Sep-07	WI	248.5	201.7	23
PRF-1	16-Sep-07	PI	142.7	57.7	147
PRF-2	16-Sep-07	PI	152.9	69.3	121
PRF-3	16-Sep-07	PI	200.9	71.0	183
PRG-1	16-Sep-07	PI	276.2	250.8	10
PRG-2	16-Sep-07	PI	181.5	137.4	32
PRG-3	16-Sep-07	PI	282.6	163.4	73

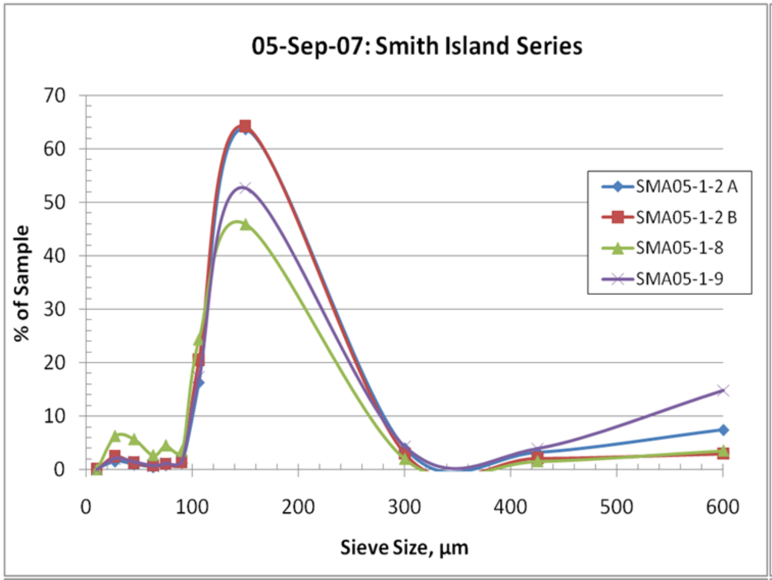
5. Soil Grain Size Distribution Data

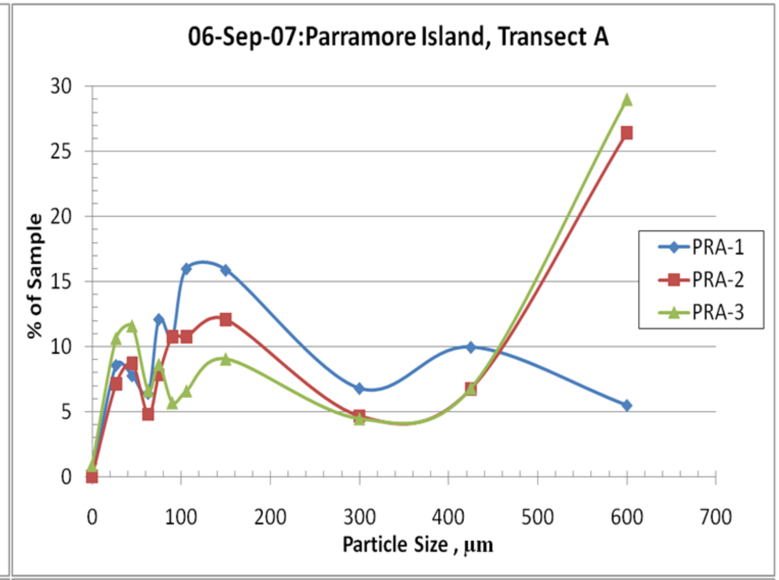
		Soil Grain Size Distribution (%)											
Date	Sample Name	600µm	425µm	300µm	150µm	106µm	90µm	75µm	63µm	45µm	27µm	10µm	Total
05-Sep-07	SMA05-1-2 A	7.45	3.20	4.00	63.65	16.30	1.30	0.90	0.50	1.00	1.57	0.12	100
05-Sep-07	SMA05-1-2 B	2.99	2.15	3.02	64.21	20.51	1.41	1.06	0.76	1.29	2.49	0.10	100.00
05-Sep-07	SMA05-1-8	3.54	1.56	2.03	45.88	24.31	3.46	4.53	2.68	5.69	6.27	0.03	100.00
05-Sep-07	SMA05-1-9	14.81	3.91	4.29	52.71	17.34	1.62	1.14	0.70	1.42	2.07	0.00	100.00
06-Sep-07	PRA-1	5.51	9.98	6.81	15.89	16.00	10.76	12.12	6.43	7.79	8.59	0.11	100.00
06-Sep-07	PRA-2	26.43	6.76	4.67	12.09	10.76	10.76	7.83	4.79	8.73	7.15	0.02	100.00
06-Sep-07	PRA-3	28.99	6.80	4.47	9.06	6.60	5.70	8.63	6.63	11.59	10.64	0.88	100.00
06-Sep-07	PRB-1	15.81	5.20	3.24	11.60	17.93	11.02	11.10	6.56	9.47	8.01	0.06	100.00
06-Sep-07	PRB-2	5.28	2.62	1.78	9.36	22.64	12.73	13.69	7.76	12.00	11.51	0.63	100.00
06-Sep-07	PRB-3	22.83	3.60	2.59	6.61	17.07	13.26	15.20	6.57	7.56	4.52	0.19	100.00
06-Sep-07	PRB-4	18.03	4.75	3.89	12.77	33.23	14.03	8.13	2.61	1.82	0.74	0.00	100.00
06-Sep-07	PRB-4 (Veg on)	19.22	7.69	4.68	10.45	10.90	7.79	10.70	6.08	9.84	11.99	0.68	100.00
06-Sep-07	PRS (LWD)	37.38	4.75	3.30	8.08	8.69	7.36	8.85	5.29	9.53	6.72	0.06	100.00
07-Sep-07	HIA-1	0.18	0.72	5.45	83.85	9.35	0.36	0.07	0.01	0.00	0.00	0.00	100.00
07-Sep-07	HIA-2	0.13	0.51	4.75	84.15	9.99	0.35	0.10	0.02	0.00	0.00	0.00	100.00
07-Sep-07	HIA-3	0.06	0.58	4.69	83.66	10.41	0.46	0.11	0.02	0.01	0.00	0.00	100.00
07-Sep-07	HIA-4	0.01	0.26	5.58	82.74	10.85	0.41	0.11	0.02	0.01	0.00	0.00	100.00
07-Sep-07	HIA-5	0.17	1.28	2.80	84.28	10.66	0.61	0.18	0.03	0.00	0.00	0.00	100.00
07-Sep-07	HIA-6	0.24	2.12	4.73	87.72	4.70	0.35	0.10	0.02	0.01	0.01	0.00	100.00
07-Sep-07	HIA-7	0.00	0.00	0.39	87.84	10.35	1.02	0.31	0.07	0.01	0.00	0.00	100.00
07-Sep-07	HIA-8	0.00	0.01	1.19	82.17	14.06	1.86	0.60	0.09	0.02	0.00	0.00	100.00
07-Sep-07	HIA-10	0.00	0.00	0.22	72.50	24.67	1.99	0.53	0.07	0.01	0.00	0.00	100.00
07-Sep-07	HIA-11	0.00	0.00	0.01	66.70	26.96	4.95	1.21	0.15	0.02	0.00	0.00	100.00
07-Sep-07	HIA-12	0.09	0.06	0.30	84.97	13.01	1.11	0.37	0.06	0.03	0.01	0.00	100.00
07-Sep-07	HIA-13	0.04	0.02	0.44	87.22	10.53	1.30	0.37	0.06	0.02	0.01	0.00	100.00
07-Sep-07	HIA-14	2.05	0.86	1.17	71.75	16.97	2.41	1.38	0.83	1.21	1.20	0.00	99.83
07-Sep-07	HIA-15	1.43	0.66	1.03	67.78	24.54	1.97	1.06	0.49	0.58	0.45	0.00	99.99
07-Sep-07	HIA-16	0.88	0.42	0.82	62.91	27.06	2.61	1.83	0.95	1.34	1.12	0.00	99.96
07-Sep-07	HIA-17	1.51	0.43	0.66	59.26	31.16	1.97	1.36	0.83	1.24	1.44	0.00	99.87
07-Sep-07	HIA-18	1.16	0.80	1.20	64.11	29.45	1.29	0.63	0.31	0.47	0.51	0.00	99.92
07-Sep-07	HIA-19	2.59	1.45	1.95	59.99	30.69	1.42	0.62	0.25	0.35	0.67	0.00	99.98
07-Sep-07	HIB-1	0.09	0.37	3.32	85.78	9.98	0.36	0.06	0.02	0.02	0.00	0.00	100.00
07-Sep-07	HIB-2	0.14	0.24	1.87	89.50	7.58	0.58	0.09	0.00	0.00	0.00	0.00	100.00
07-Sep-07	HIB-3	0.10	0.91	6.62	85.68	5.93	0.49	0.23	0.04	0.01	0.00	0.00	100.00
07-Sep-07	HIB-4	0.07	0.37	2.24	86.82	9.92	0.47	0.10	0.02	0.00	0.00	0.00	100.00
07-Sep-07	HIB-5	0.06	0.21	0.85	84.66	13.45	0.64	0.10	0.02	0.00	0.00	0.00	100.00
07-Sep-07	HIB-6	0.00	0.03	0.77	90.71	7.77	0.51	0.17	0.03	0.01	0.00	0.00	100.00
07-Sep-07	HIB-7	0.00	0.07	1.12	90.04	6.99	1.24	0.41	0.10	0.03	0.00	0.00	100.00
07-Sep-07	HIB-8	0.00	0.00	0.45	79.39	16.26	2.59	1.11	0.16	0.04	0.00	0.00	100.00
07-Sep-07	HIB-9	0.00	0.00	0.31	85.93	11.29	1.85	0.52	0.09	0.00	0.00	0.00	100.00

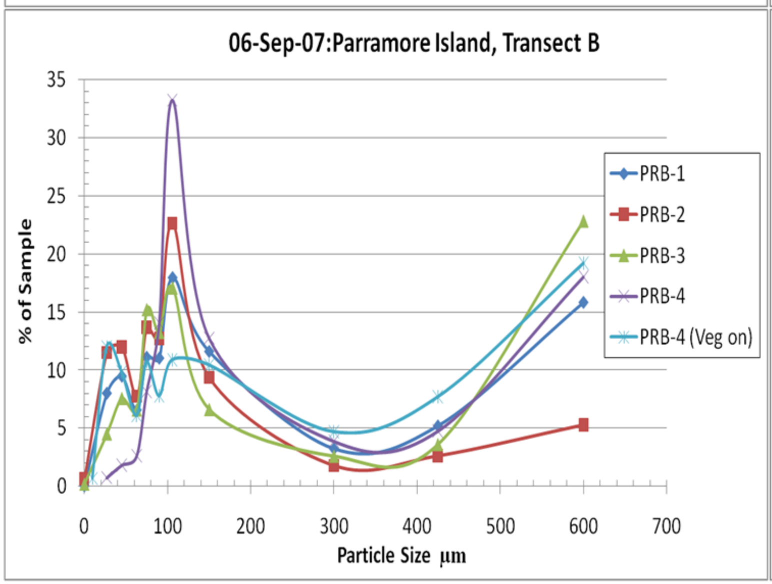
		Soil Grain Size Distribution (%)											
Date	**Sample Name**	**600µm**	**425µm**	**300µm**	**150µm**	**106µm**	**90µm**	**75µm**	**63µm**	**45µm**	**27µm**	**10µm**	**Total**
08-Sep-07	NSA-1	0.01	0.34	1.93	91.45	5.86	0.27	0.05	0.03	0.01	0.02	0.02	100.00
08-Sep-07	NSA-2	0.05	0.40	3.37	90.91	4.33	0.77	0.13	0.04	0.02	0.00	0.00	100.00
08-Sep-07	NSA-3	0.07	0.14	1.19	93.86	4.15	0.47	0.10	0.02	0.00	0.00	0.00	100.00
08-Sep-07	NSA-4	0.00	0.01	0.40	91.80	5.59	1.42	0.56	0.15	0.05	0.00	0.01	100.00
08-Sep-07	NSA-5	1.04	0.04	0.20	80.82	16.20	1.20	0.37	0.10	0.04	0.00	0.00	100.00
08-Sep-07	NSA-6	2.90	1.70	3.17	83.97	7.44	0.55	0.22	0.04	0.00	0.00	0.00	100.00
08-Sep-07	NSA-7	0.02	0.02	1.02	90.96	6.85	0.80	0.28	0.05	0.00	0.00	0.00	100.00
08-Sep-07	NSA-8	0.27	3.32	19.39	71.11	5.35	0.47	0.09	0.00	0.00	0.00	0.00	100.00
08-Sep-07	NSA-9	0.64	2.07	7.38	78.83	8.84	1.58	0.48	0.12	0.05	0.00	0.00	100.00
08-Sep-07	NSA-10	0.79	2.79	10.84	79.37	5.75	0.36	0.09	0.00	0.00	0.00	0.00	100.00
08-Sep-07	NSA-11	0.21	0.97	3.19	90.48	4.78	0.30	0.07	0.01	0.00	0.00	0.00	100.00
08-Sep-07	NSB-1	10.54	3.22	2.39	8.30	12.56	6.43	11.78	9.70	17.85	16.74	0.49	100.00
08-Sep-07	NSB-2	17.79	5.13	3.56	9.78	9.24	5.67	8.35	7.83	13.90	17.64	1.11	100.00
08-Sep-07	NSB-3	12.62	3.98	3.14	12.15	10.75	5.61	8.76	6.98	17.41	17.65	0.93	100.00
08-Sep-07	NSB-4	13.20	3.32	2.70	25.41	18.59	5.56	5.32	6.79	9.94	8.68	0.47	100.00
08-Sep-07	NSB-5	3.43	0.93	0.82	59.50	24.87	2.59	2.08	1.28	2.02	2.35	0.14	100.00
08-Sep-07	NSB-7	0.66	0.78	2.30	75.34	19.39	1.03	0.31	0.09	0.06	0.04	0.00	100.00
08-Sep-07	NSB-8	12.58	4.86	3.98	21.45	12.98	4.10	5.45	5.18	11.40	17.10	0.91	100.00
08-Sep-07	NSB-9	12.86	3.19	2.43	17.69	14.47	5.81	7.61	6.70	15.26	13.62	0.35	100.00
08-Sep-07	NSB-10	40.14	9.41	9.39	36.74	3.89	0.15	0.08	0.07	0.07	0.07	0.00	100.00
08-Sep-07	NSB-11	30.73	5.56	12.76	48.90	1.91	0.07	0.03	0.02	0.00	0.00	0.00	100.00
08-Sep-07	NSB-13	0.04	0.04	0.86	66.84	26.86	4.10	1.05	0.13	0.02	0.03	0.03	100.00
08-Sep-07	NSB-14	3.92	0.80	1.39	66.63	23.45	3.11	0.61	0.07	0.02	0.00	0.00	100.00
08-Sep-07	NSB-15	1.93	6.89	14.51	71.03	5.08	0.39	0.12	0.04	0.00	0.00	0.00	100.00
10-Sep-07	WB-1	6.33	1.87	2.14	31.65	35.36	7.03	5.17	3.28	3.97	3.07	0.12	100.00
10-Sep-07	WB-2	4.64	3.30	4.01	33.53	29.71	6.22	5.29	3.28	4.75	5.01	0.25	100.00
10-Sep-07	WB-3	5.72	1.95	2.45	51.87	24.18	3.93	2.69	1.43	2.72	2.99	0.07	100.00
10-Sep-07	WB-4	2.29	3.10	2.96	39.27	35.51	4.29	4.08	3.10	3.21	2.14	0.04	100.00
12-Sep-07	PRD01	0.13	0.68	3.60	89.02	5.21	0.85	0.24	0.03	0.24	0.00	0.00	100.00
12-Sep-07	PRD02	0.01	0.27	1.98	91.45	5.47	0.54	0.22	0.05	0.02	0.00	0.00	100.00
12-Sep-07	PRD03	0.00	0.04	1.81	87.96	8.35	1.22	0.52	0.09	0.01	0.00	0.00	100.00
12-Sep-07	PRD04	0.00	0.03	1.83	90.97	6.26	0.67	0.20	0.04	0.01	0.00	0.00	100.00
12-Sep-07	PRD05	0.14	2.08	11.24	81.95	4.31	0.23	0.04	0.01	0.00	0.00	0.00	100.00
12-Sep-07	PRD06	0.22	1.40	8.23	84.67	4.78	0.55	0.11	0.02	0.00	0.00	0.00	100.00
12-Sep-07	PRE03	0.01	0.12	2.19	90.59	5.45	1.09	0.50	0.03	0.01	0.01	0.00	100.00
12-Sep-07	PRE04	0.10	0.11	3.80	89.56	5.21	0.84	0.37	0.01	0.00	0.00	0.00	100.00
12-Sep-07	PRASWB	11.35	4.32	3.80	17.30	10.33	7.54	0.28	15.32	13.82	15.20	0.73	100.00

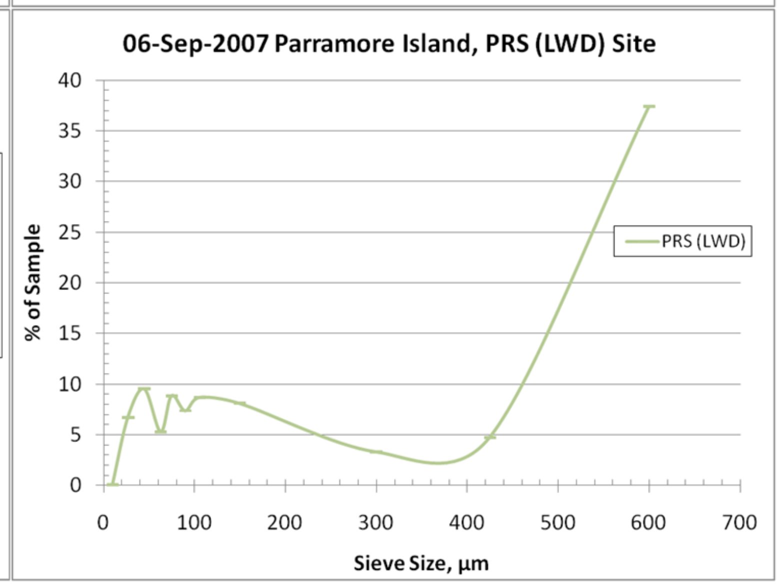
		Soil Grain Size Distribution (%)											
Date	**Sample Name**	**600µm**	**425µm**	**300µm**	**150µm**	**106µm**	**90µm**	**75µm**	**63µm**	**45µm**	**27µm**	**10µm**	**Total**
13-Sep-07	WIC-1	0.51	1.77	4.89	76.77	15.40	0.51	0.12	0.03	0.00	0.00	0.00	100.00
13-Sep-07	WIC-2	0.75	0.79	1.55	81.54	13.50	0.55	0.34	0.16	0.36	0.37	0.07	100.00
13-Sep-07	WIC-3	0.05	0.53	1.77	84.24	12.19	0.52	0.26	0.14	0.18	0.11	0.01	100.00
13-Sep-07	WIC-4	2.11	5.43	15.76	74.81	1.56	0.24	0.07	0.03	0.00	0.00	0.00	100.00
13-Sep-07	WIC-5	0.36	0.91	5.19	88.52	4.71	0.21	0.08	0.02	0.00	0.00	0.00	100.00
13-Sep-07	WIC-6	0.45	0.66	5.04	86.72	7.01	0.00	0.08	0.02	0.00	0.00	0.00	100.00
13-Sep-07	WIC-7	1.89	0.96	6.97	86.59	3.35	0.15	0.05	0.02	0.03	0.00	0.00	100.00
13-Sep-07	WIC-8	0.15	0.22	1.55	74.95	11.59	2.46	2.36	1.48	2.88	2.15	0.20	100.00
13-Sep-07	WIC-9	0.63	0.72	4.22	76.32	1.61	2.31	2.53	9.37	1.82	0.46	0.01	100.00
13-Sep-07	WIC-10	2.24	0.17	0.86	63.57	22.76	2.05	1.75	1.62	3.27	1.69	0.02	100.00
13-Sep-07	WIC-11	0.11	0.64	4.21	75.21	10.76	2.94	3.20	1.97	0.79	0.16	0.00	100.00
13-Sep-07	WIC-12	17.18	6.28	6.93	52.43	12.05	1.80	1.52	1.02	0.58	0.21	0.00	100.00
13-Sep-07	WIC-13	0.12	0.31	1.14	77.92	16.09	1.75	1.07	0.75	0.65	0.18	0.00	100.00
13-Sep-07	WIC-14	1.41	0.50	3.10	81.03	10.19	1.27	1.13	0.76	0.55	0.05	0.00	100.00
16-Sep-07	PRF-1	0.26	1.01	1.92	73.84	21.15	1.22	0.47	0.08	0.03	0.00	0.00	100.00
16-Sep-07	PRF-2	8.31	3.39	3.56	63.27	18.85	1.59	0.61	0.24	0.13	0.05	0.00	100.00
16-Sep-07	PRF-3	15.49	3.06	2.76	55.96	17.16	2.12	1.35	0.72	0.82	0.55	0.00	100.00
16-Sep-07	PRG-1	15.89	6.30	5.37	40.89	17.16	2.26	1.63	1.30	2.22	4.77	2.20	100.00
16-Sep-07	PRG-2	17.38	5.97	4.75	39.10	20.62	2.49	1.72	1.22	3.88	2.83	0.03	100.00
16-Sep-07	PRG-3	38.98	7.55	5.52	25.83	11.83	2.02	1.53	1.13	1.90	3.34	0.38	100.00

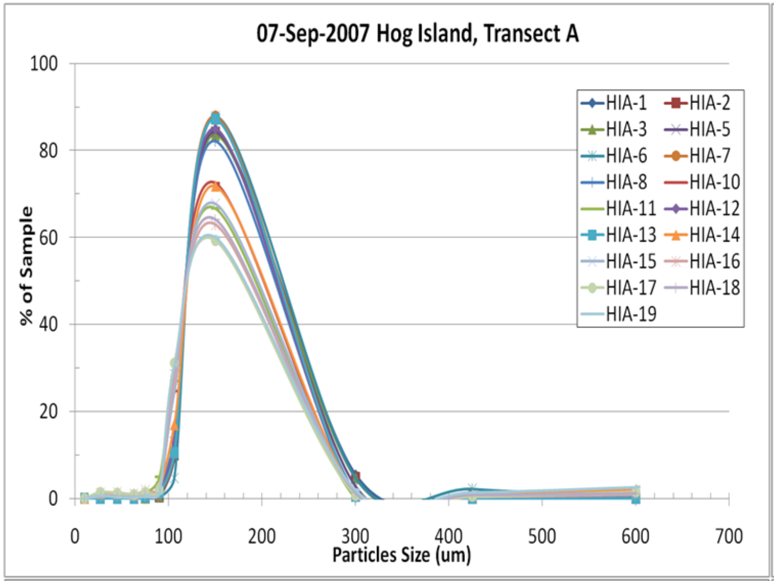
6. Soil Grain Size Distribution Graphs

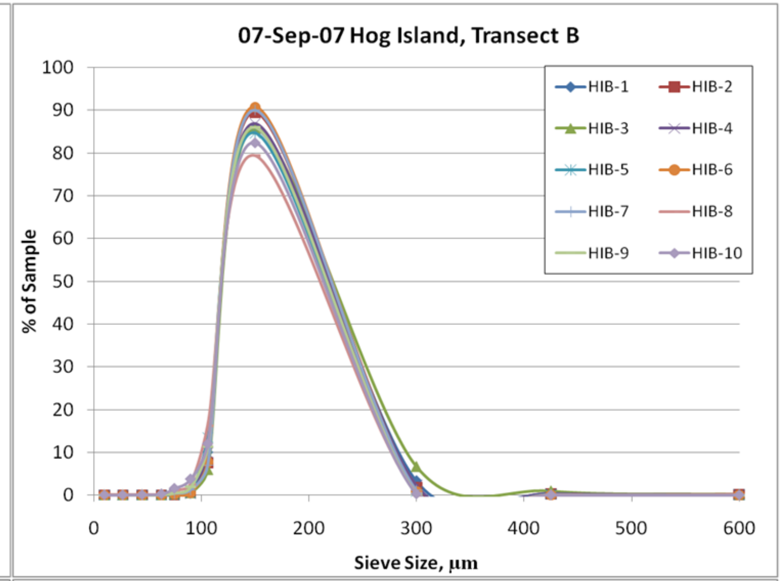


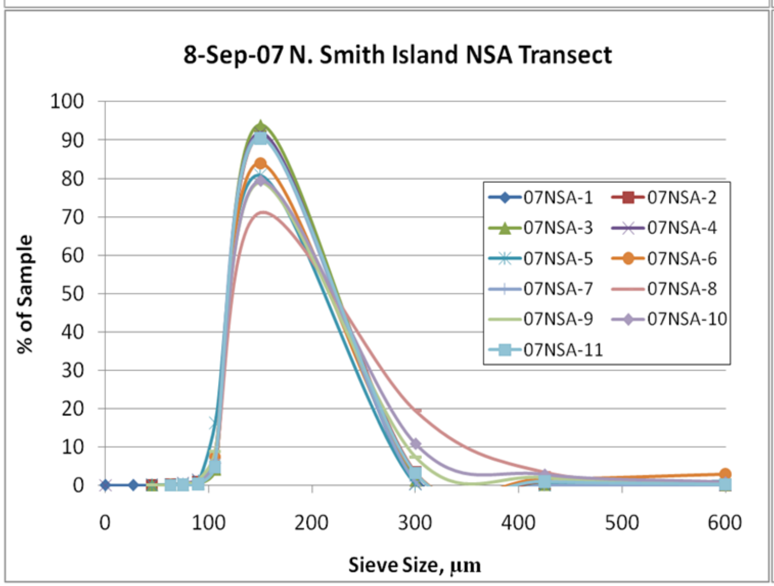


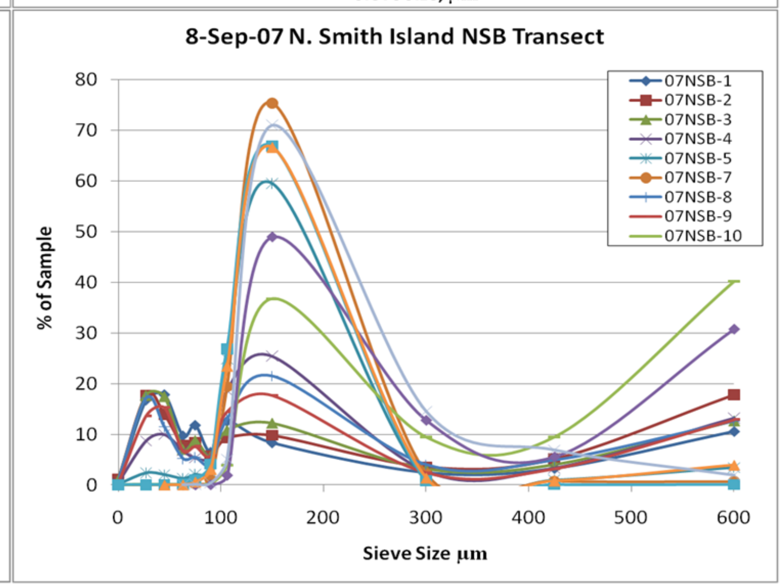


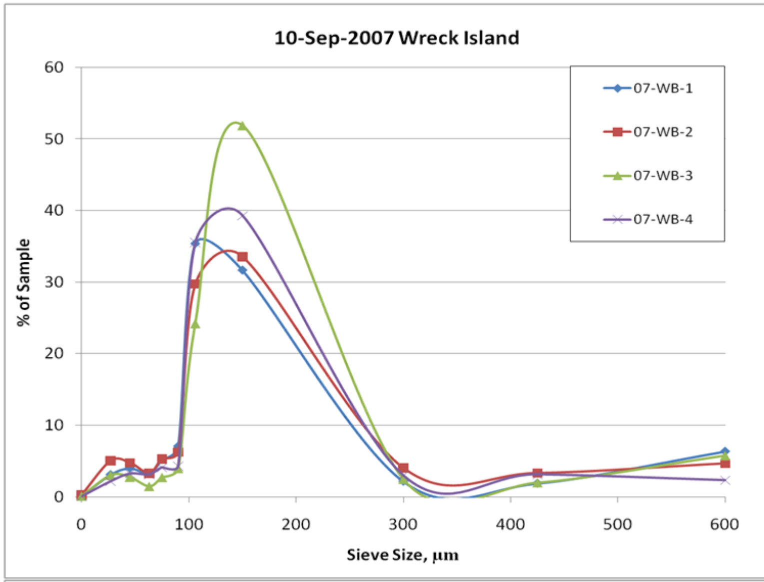


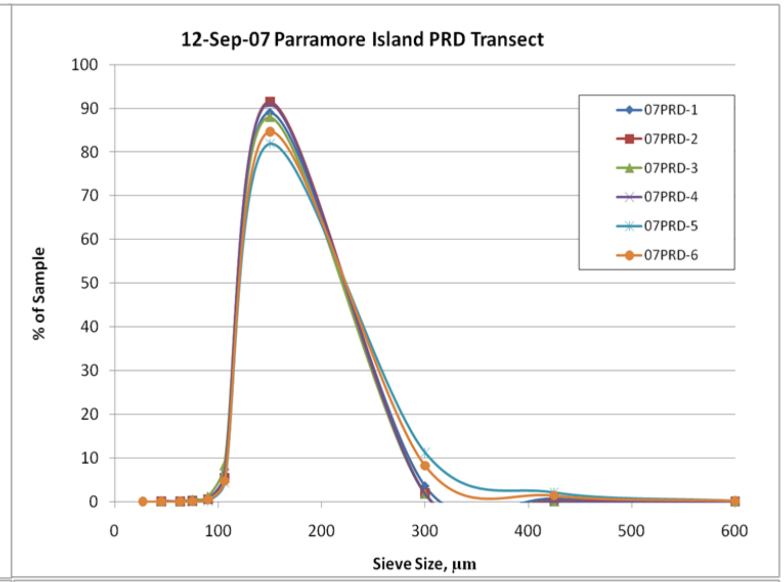

07-Sep-2007 Hog Island, Transect A
% of Sample
Particles Size (um)
HIA-1
HIA-2
HIA-3
HIA-5
HIA-6
HIA-7
HIA-8
HIA-10
HIA-11
HIA-12
HIA-13
HIA-14
HIA-15
HIA-16
HIA-17
HIA-18
HIA-19

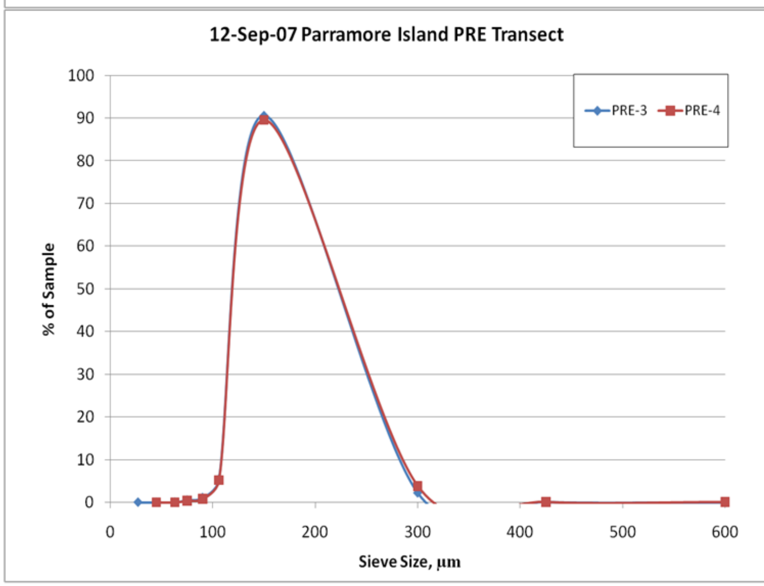

07-Sep-07 Hog Island, Transect B
% of Sample
Sieve Size, µm
HIB-1
HIB-2
HIB-3
HIB-4
HIB-5
HIB-6
HIB-7
HIB-8
HIB-9
HIB-10

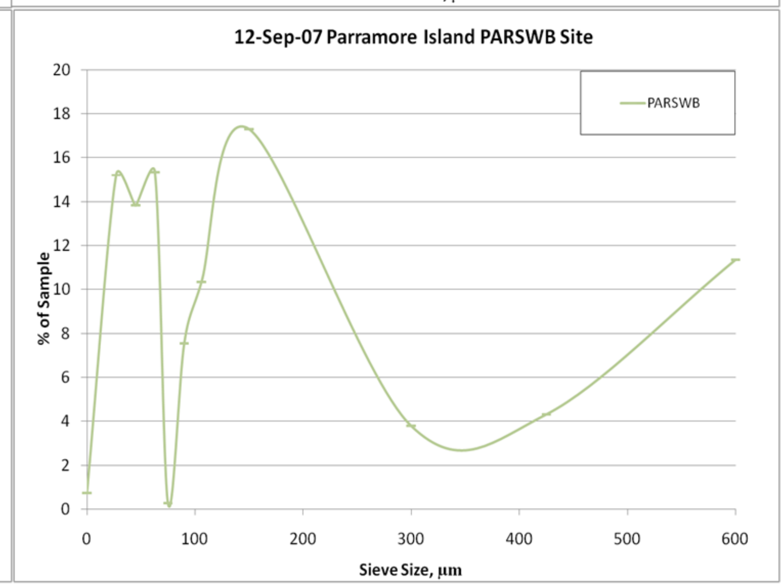

8-Sep-07 N. Smith Island NSA Transect
% of Sample
Sieve Size, µm
07NSA-1
07NSA-2
07NSA-3
07NSA-4
07NSA-5
07NSA-6
07NSA-7
07NSA-8
07NSA-9
07NSA-10
07NSA-11

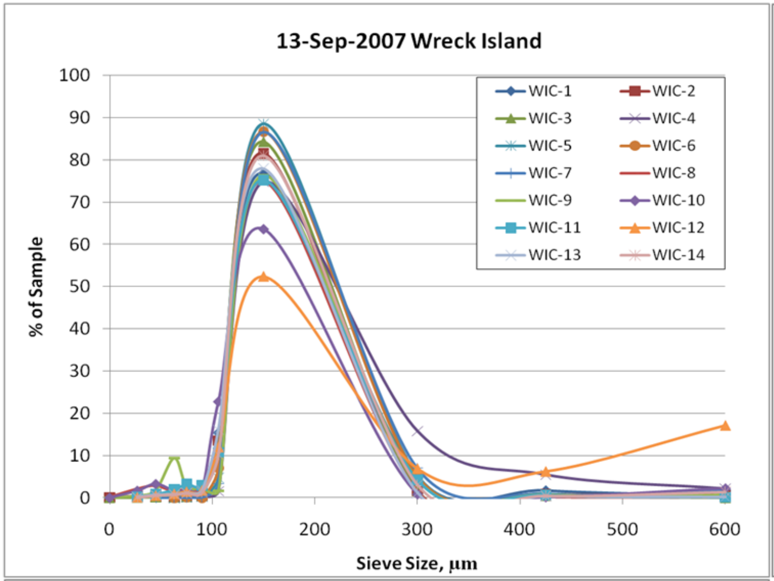

8-Sep-07 N. Smith Island NSB Transect
% of Sample
Sieve Size µm
07NSB-1
07NSB-2
07NSB-3
07NSB-4
07NSB-5
07NSB-7
07NSB-8
07NSB-9
07NSB-10

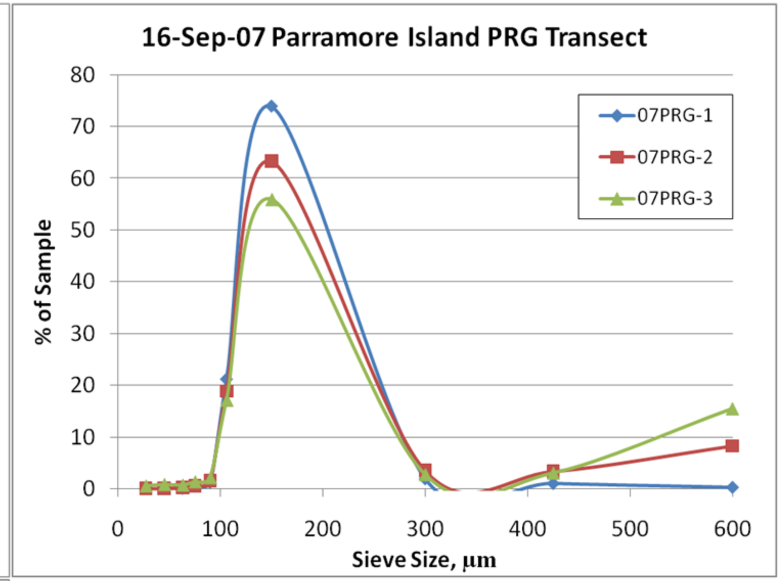

10-Sep-2007 Wreck Island
07-WB-1
07-WB-2
07-WB-3
07-WB-4
% of Sample
Sieve Size, µm

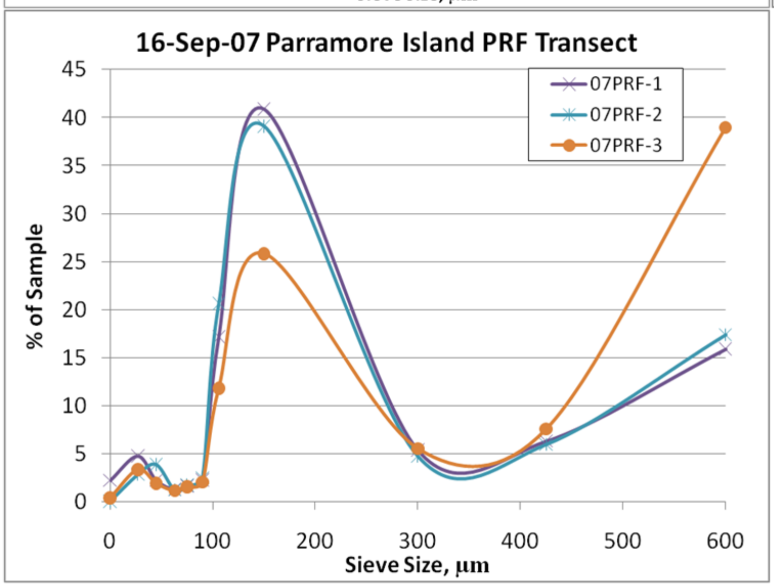

12-Sep-07 Parramore Island PRD Transect
07PRD-1
07PRD-2
07PRD-3
07PRD-4
07PRD-5
07PRD-6
% of Sample
Sieve Size, µm


12-Sep-07 Parramore Island PRE Transect
PRE-3
PRE-4
% of Sample
Sieve Size, µm


12-Sep-07 Parramore Island PARSWB Site
PARSWB
% of Sample
Sieve Size, µm


13-Sep-2007 Wreck Island
% of Sample
Sieve Size, µm
WIC-1
WIC-2
WIC-3
WIC-4
WIC-5
WIC-6
WIC-7
WIC-8
WIC-9
WIC-10
WIC-11
WIC-12
WIC-13
WIC-14


16-Sep-07 Parramore Island PRG Transect
% of Sample
Sieve Size, µm
07PRG-1
07PRG-2
07PRG-3


16-Sep-07 Parramore Island PRF Transect
% of Sample
Sieve Size, µm
07PRF-1
07PRF-2
07PRF-3

APPENDIX I

Weather Records

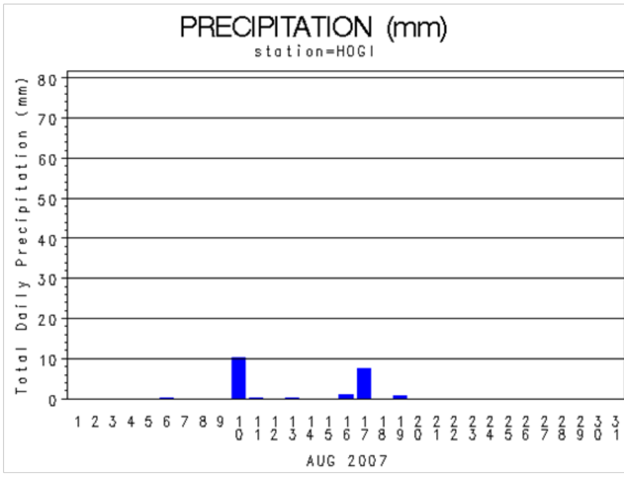
1. Introduction

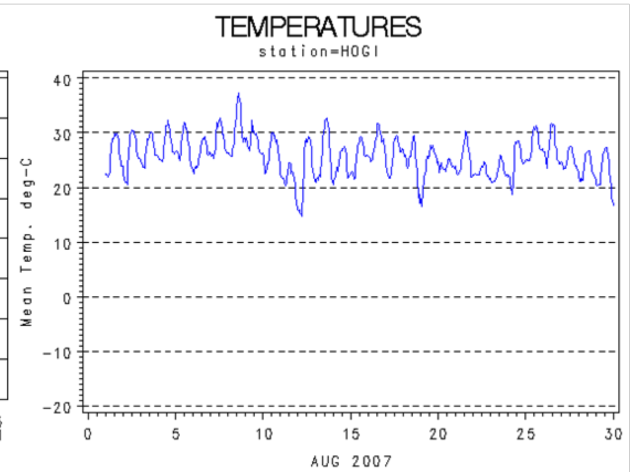
Weather records are displayed for the months of August and September 2007. The source for weather data and graphics is the VCR LTER website (http://www.vcrlter.virginia.edu/data/metdata/index.html) .The recording station for weather data is Hog Island (HOGI) weather station located at (37° 23' 42" N, 75° 42' 36" W).

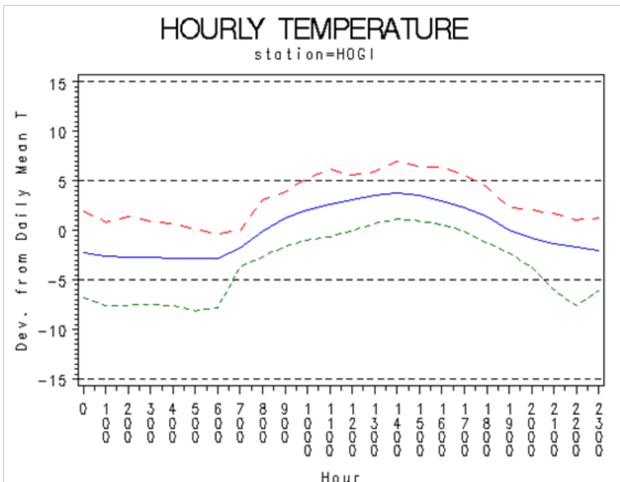
2. Tabular Monthly Summary for August 2007

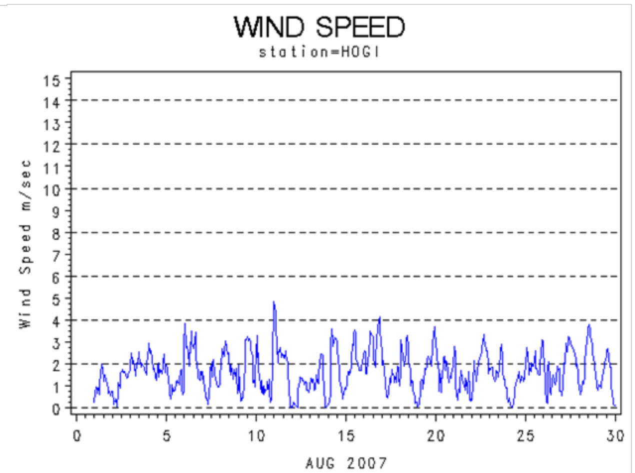
Day of Month	Precip (mm)	Max Temp. °C	Min Temp. °C	Mean Temp. °C	Wind Speed (m/s)	Wind Dir (deg.)	Vapor Press. (mb)	Solar Rad. KJ/m²	PAR uE/m²
1	0.00	30	22	26.1	1.02	295	25.60	27818	19513
2	0.00	31	20	26.1	1.09	175	24.64	28323	21427
3	0.00	31	23	26.8	1.97	169	26.71	27717	20008
4	0.00	33	25	27.7	1.95	159	29.07	25687	18467
5	0.00	32	23	27.6	1.07	164	29.17	19328	14158
6	0.25	30	22	26.0	2.43	163	28.72	21721	17909
7	0.00	33	25	28.6	1.13	175	32.39	23525	17405
8	0.00	38	25	30.3	2.00	148	31.81	24624	17954
9	0.00	33	26	28.4	1.77	327	30.63	23999	17263
10	10.16	31	22	26.6	1.34	330	29.81	11886	10279
11	0.25	26	16	21.6	2.31	339	20.33	13503	10780
12	0.00	30	15	22.8	0.73	238	19.01	28472	25732
13	0.25	33	21	26.1	1.21	77	22.68	24958	23373
14	0.00	28	20	24.2	1.73	320	19.39	27621	24505
15	0.00	30	21	25.6	2.03	172	22.54	25248	21943
16	1.02	32	24	27.8	2.80	160	30.23	22507	19826
17	7.62	30	21	25.9	1.37	139	27.85	21681	18741
18	0.00	30	17	24.8	1.65	358	17.50	27036	20684
19	0.76	28	16	24.0	1.75	179	21.67	15204	13205
20	0.00	26	22	23.9	1.72	289	25.62	12627	10423
21	0.00	31	22	25.1	1.08	300	27.09	22010	16236
22	0.00	25	21	22.8	2.05	333	24.69	11716	9742
23	0.00	26	21	22.8	1.65	335	24.02	15511	12429
24	0.00	29	19	24.6	0.85	205	25.00	24036	18991
25	0.00	32	25	27.7	2.03	163	30.45	24303	18389
26	0.00	32	23	27.3	1.26	143	29.60	20101	14840
27	0.00	28	23	25.0	2.22	319	25.95	23195	2498
28	0.00	27	21	23.7	2.10	320	23.48	25710	2224
29	0.00	28	17	23.0	1.40	312	19.98	25968	13869
30	0.00	29	16	22.3	1.19	309	19.11	24953	21879
31	0.00	30	17	24.0	1.19	334	22.59	22809	11993

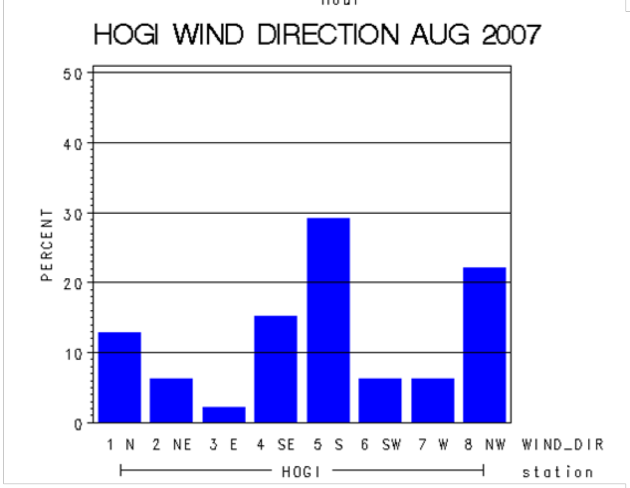
3. Graphic Displays for August 2007

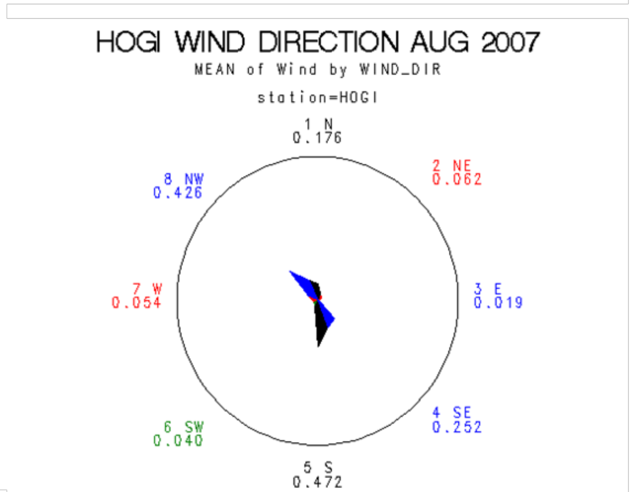


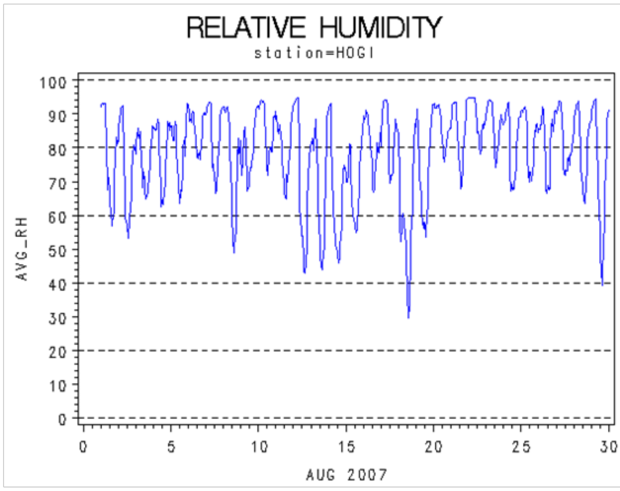


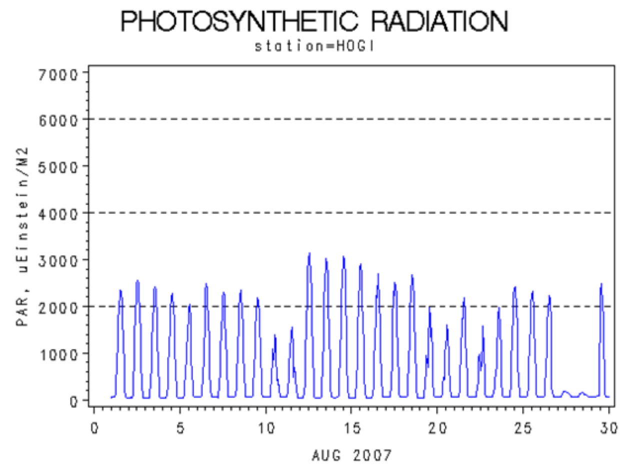


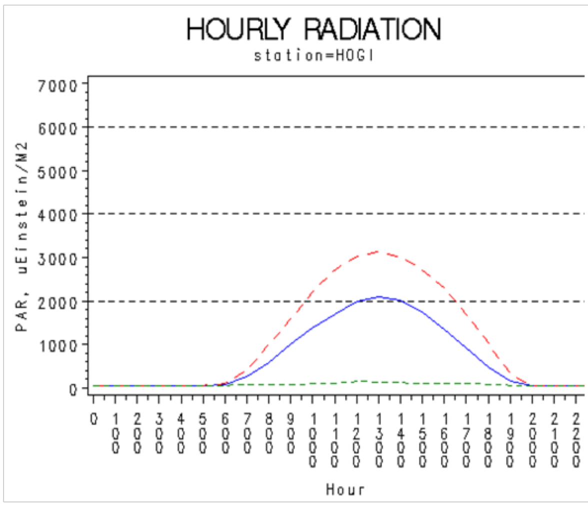


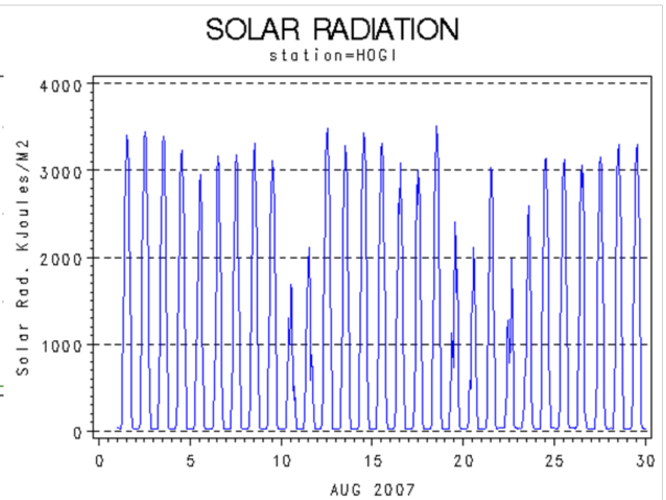





RELATIVE HUMIDITY
station=HOGI
AVG_RH
AUG 2007


PHOTOSYNTHETIC RADIATION
station=HOGI
PAR, uEinstein/M2
AUG 2007

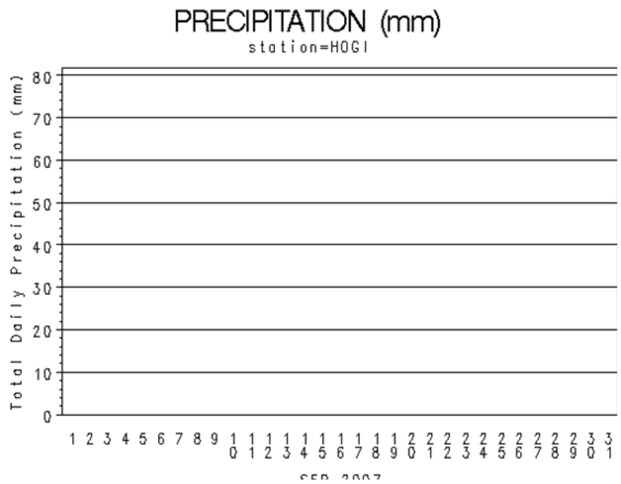

HOURLY RADIATION
station=HOGI
PAR, uEinstein/M2
Hour

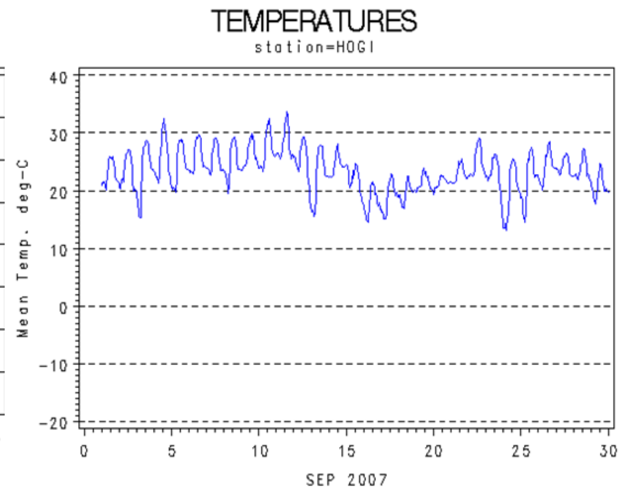

SOLAR RADIATION
station=HOGI
Solar Rad. KJoules/M2
AUG 2007

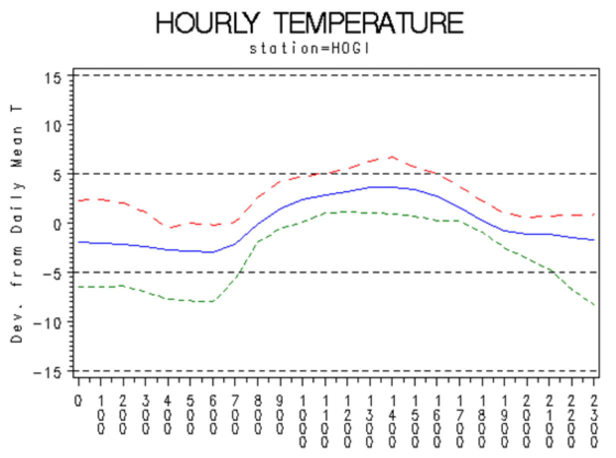
4. Tabular Monthly Summary for September 2007

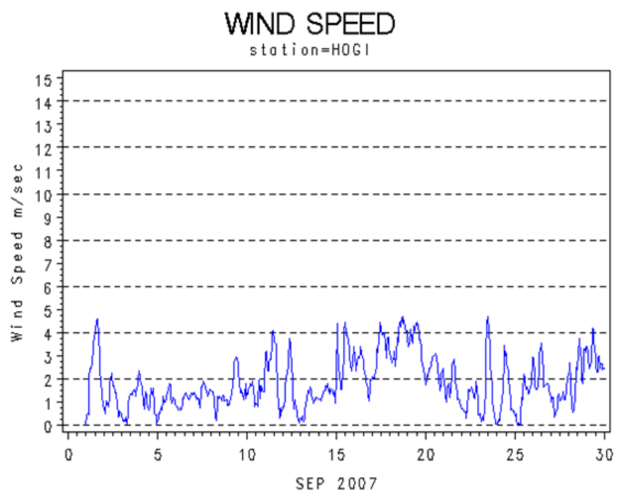
Day of Month	Precip (mm)	Max Temp. ºC	Min Temp. ºC	Mean Temp. ºC	Wind Speed (m/s)	Wind Dir (deg.)	Vapor Press. (mb)	Solar Rad. KJ/m²	PAR uE/m²
1	0.00	26	20	23.0	2.50	327	19.67	25604	13659
2	0.00	28	20	23.4	1.12	282	15.90	25912	12018
3	0.00	29	15	23.2	1.00	186	20.14	25099	21790
4	0.00	33	20	25.8	1.10	148	22.67	23846	19441
5	0.00	29	19	24.5	1.02	280	24.82	23856	13552
6	0.00	30	23	25.8	1.04	215	23.90	22813	19421
7	0.00	30	22	25.5	1.38	184	22.75	21684	18043
8	0.00	30	19	24.9	1.04	200	21.03	24005	9416
9	0.00	30	23	26.2	1.78	281	27.04	21367	15002
10	0.00	33	23	27.2	1.41	71	26.95	18790	14174
11	0.00	34	25	28.0	2.44	139	25.91	20225	14755
12	0.00	31	17	25.0	1.48	8	16.74	22145	15996
13	0.00	29	15	22.7	0.93	250	17.05	21367	15252
14	0.00	29	22	24.4	1.36	242	21.07	13479	10332
15	0.00	25	18	22.1	2.92	37	18.30	19900	18983
16	0.00	22	14	18.0	2.39	344	11.50	20249	17286
17	0.00	24	15	18.9	3.25	332	13.28	18815	16128
18	0.00	23	17	19.6	3.68	336	15.74	10610	9084
19	0.00	24	19	21.4	3.58	322	20.03	14867	11866
20	0.00	23	19	21.4	2.42	320	21.67	6507	5966
21	0.00	26	21	22.9	1.63	302	24.37	13592	14193
22	0.00	30	22	24.9	1.08	184	26.47	20281	19642
23	0.00	27	14	22.7	1.57	321	21.44	20989	18871
24	0.00	26	13	19.9	1.34	310	18.22	22449	22885
25	0.00	28	14	21.9	1.11	180	20.94	20816	21906
26	0.00	29	20	24.2	2.15	168	24.15	21435	21855
27	0.00	27	22	24.2	1.11	191	26.50	10226	11223
28	0.00	28	21	23.7	2.24	47	20.55	13858	14802
29	0.00	25	17	20.8	2.88	351	12.81	21455	20764
30	0.00	25	20	21.6	2.09	296	14.39	21099	20420

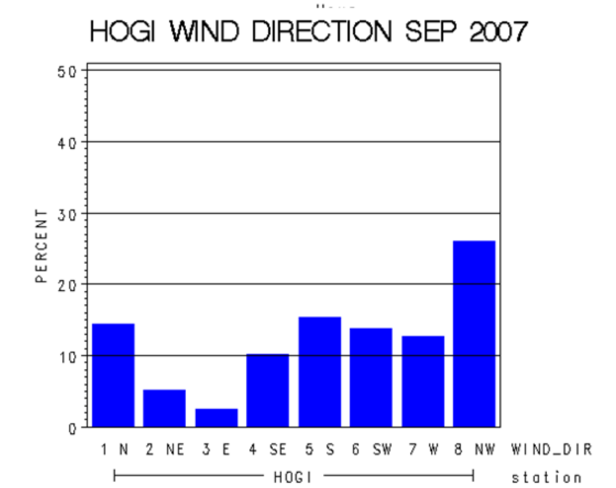
5. Graphic Displays for September 2007

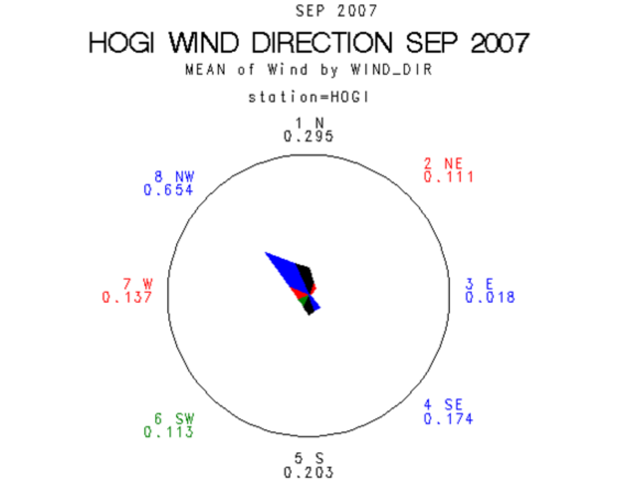


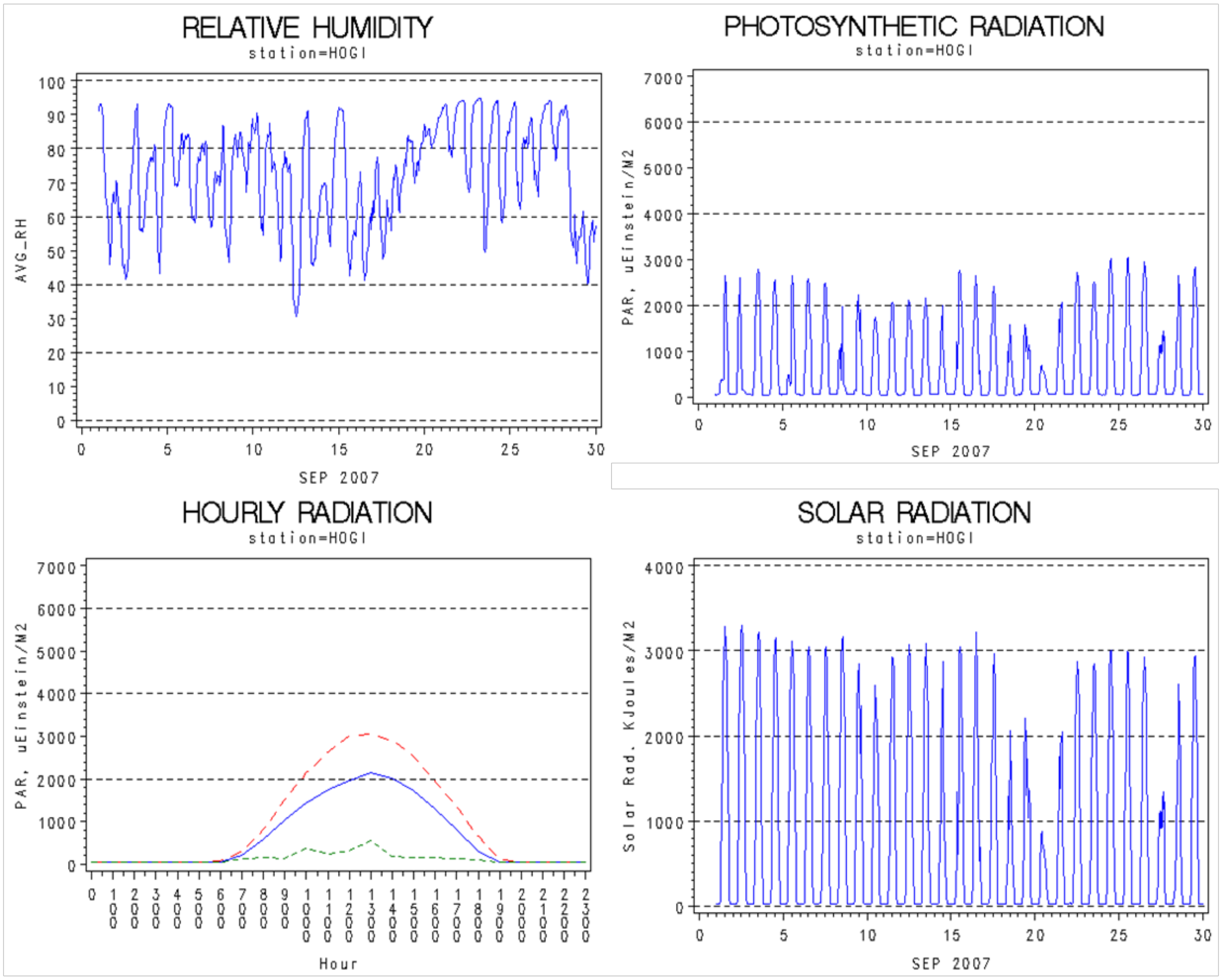











RELATIVE HUMIDITY
station=HOGI
AVG_RH
SEP 2007
PHOTOSYNTHETIC RADIATION
station=HOGI
PAR, uEinstein/M2
SEP 2007
HOURLY RADIATION
station=HOGI
PAR, uEinstein/M2
Hour
SOLAR RADIATION
station=HOGI
Solar Rad. KJoules/M2
SEP 2007

APPENDIX J

Geodatabase

1. Introduction:

A geodatabase is an information database that contains data with a geographical component meaning that it is a collection of feature datasets for use with a GIS such as ArcMap or ArcGIS Explorer. ArcMap is contained in ArcGIS and is a proprietary software program developed by Environmental Systems Research Institute, INC (ESRI). ArcGIS Explorer is a free software version of ArcGIS which was developed by ESRI and is used mainly for visualization and presentation purposes. The software program is similar to Google® Earth and allows for opening shapefiles and adding points and shapes to the viewer, but creating and editing shapefiles are not possible in this version. The VCR'07 geodatabase was developed to be viewed in both ArcGIS and ArcGIS Explorer. The ArcGIS Explorer version was made in order to accommodate those who wanted to see the positions and type of data collected but do not have access to ArcGIS. Those with access to ArcGIS and the applications of ArcMap, ArcToolbox, and ArcCatalog will have access to the full capabilities of the geodatabase and be able to create and edit data to suit their needs.

To view the geodatabases, navigate to either the *.mxd* or *.nmf* file in the VCR_GD folder in Windows Explorer. By opening the *.mxd* file, the ArcMap (ArcGIS) version of the geodatabase is opened. Clicking the *.nmf* file opens the ArcGIS Explorer 900 version.

2. ArcGIS Explorer Version

The ArcGIS Explorer version allows for the visualization and presentation of data collected at the VCR. Content in this version includes data collected at VCR as well as additional data provided by multiple sources. The viewer of ArcGIS Explorer 900 can be seen in Figure J.1. The display is similar to ArcMap which has "Tools" along the top, and a "Contents" section which displays the available layers presented in the "Map View" section. The ArcGIS Explorer 900 "Tools" section has similar tabbed navigation as the Microsoft® Office 2007 series.

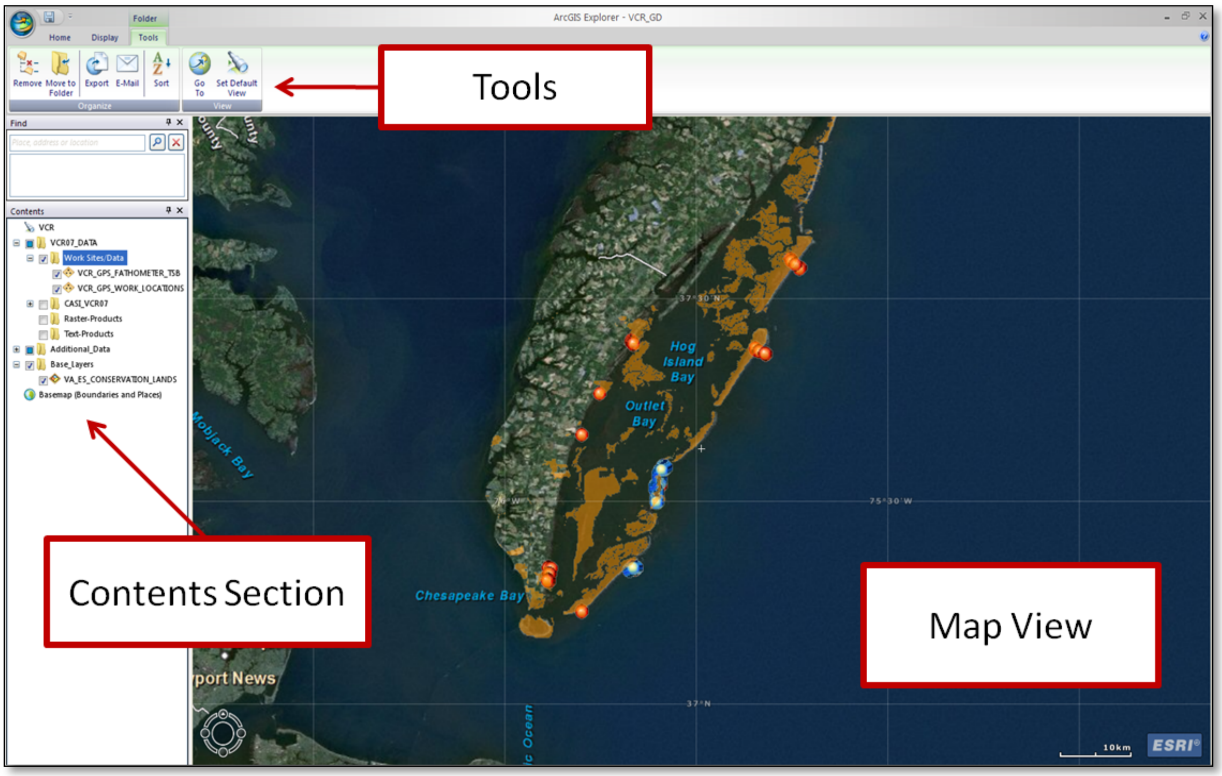


Figure J.1 Sections of ArcGIS Explorer 900.

Figure J.2 displays the items in the contents view of the ArcGIS Explorer version. The data concerning the VCR'07 campaign is broken down into three major sections. The "VCR07Data" section contains the data collected at the site by the NRL team and products developed from this data; the "Additional Data" section contains data obtained from multiple sources that complement the data collected during the VCR experiment; and the "Base Layers" section contains background shapefiles for viewing, and this section is especially useful if an internet connection cannot be obtained (ArcGIS Explorer imagery background "basemap" will not be available).

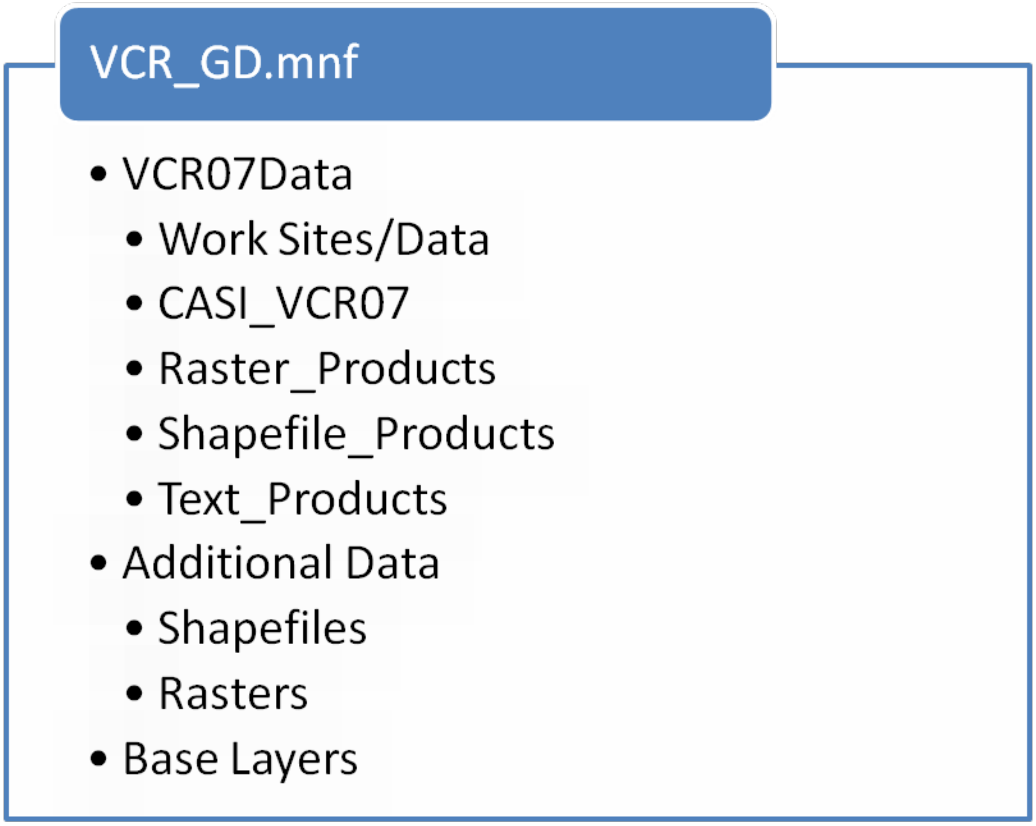


Figure J.1 ArcGIS Explorer geodatabase shapefile groupings.

Figure J.3 displays two screen captures of viewing the data. The top of the figure (marked A) displays some of the data that were collected at the VCR site. In the figure, red dots signify the GPS points where ground data were collected. The blue dots (seen center middle) display positions where bathymetry/salinity/temperature measurements were taken. CASI imagery is seen as overlapping flight lines and can be seen behind both sets of GPS data points. All three types of data can be turned off or on (viewed or not viewed) by checking or unchecking the box in the "Contents" section. The bottom of Figure J.3 (marked B) displays some additional data that had been collected via the internet. White dots represent positions where LTER had conducted studies. By clicking on each point, a pop-up window will be displayed which contains a URL to obtain the data collected at that site. Green dots represent positions of SAV growth as stated by the Virginia Institute of Marine Science. The orange base layer shapefile shows conservation lands on the eastern shore of Virginia. By clicking on the shapefile, the pop-up window displays a table containing information on the name of the land tract, the owner/management group owning the tract, a URL link to the owner's website, and other information.

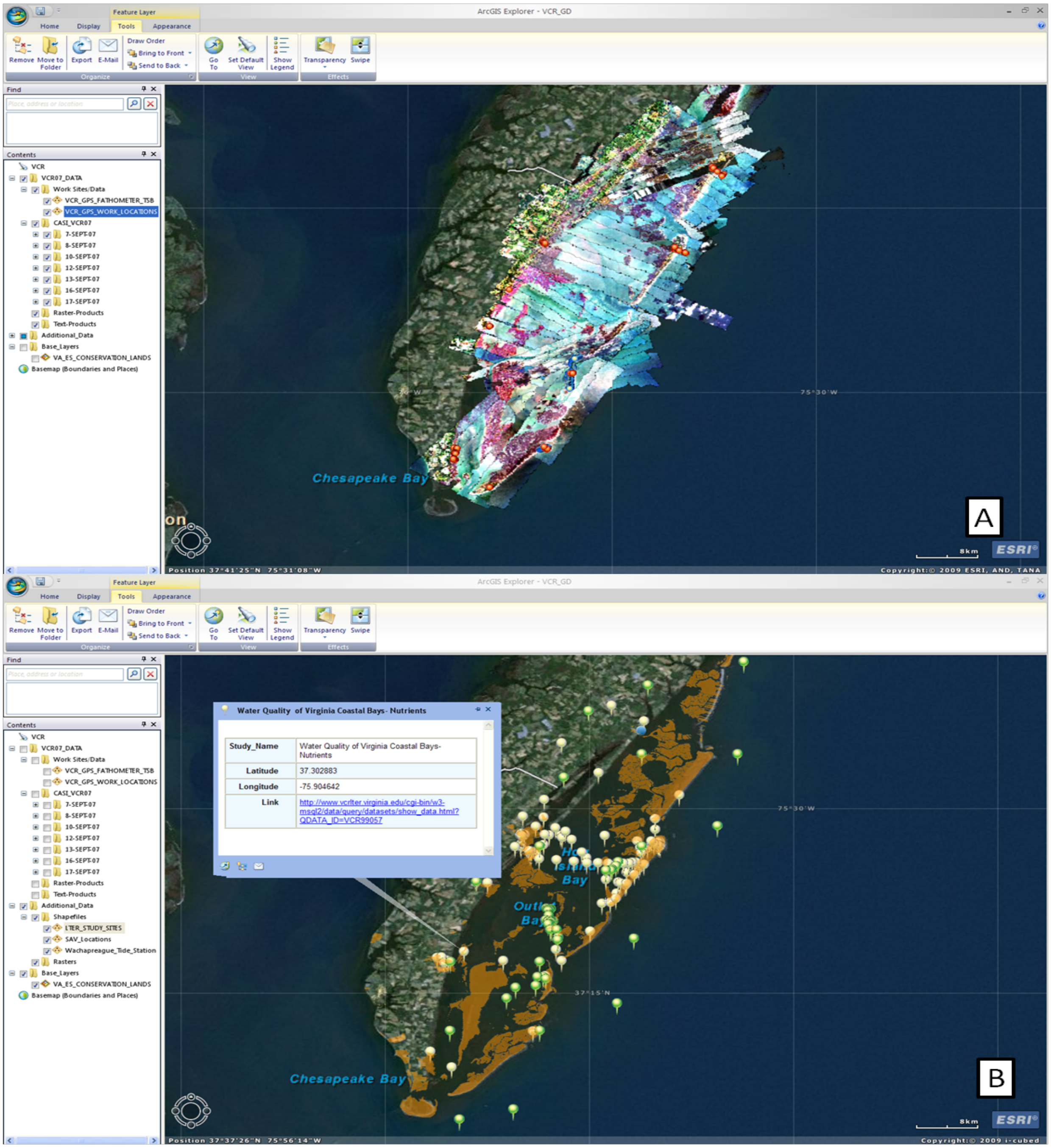


Figure J.3 Screen captures of the VCR'07 geodatabase viewed in ArcGIS Explorer 900. (A) Display of VCR07DATA collected at site. Red dots signify GPS points where data were collected. Blue dots are GPS points where bathymetry/salinity and temperature measurements were taken. CASI imagery can also be seen. (B) Display of Additional Data. White dots signify data points where LTER data had been collected. Green dots signify submerged aquatic vegetation. Orange base layer shows conservation lands located on the eastern shore of Virginia.

Figure J.4 displays two screen captures showing the access of GPS attribute data collected during the VCR'07 campaign. The top portion of the figure (marked A) shows the pop-up window that is displayed when a VCR_GPS_WORK_LOCATION point is clicked. The table shows the site's name, position, time and date, locality, whether or not certain data were collected at the site, absolute file pathnames/relative pathnames to connecting to a photograph of the site, and a link to the attribute data for all sites. The links lead to the display on the bottom portion of the figure (marked B). Part B shows the folder hierarchy viewed in Windows Explorer and has the Excel file VCR_ALL_DATA highlighted in blue. That Excel file contains all the attribute data collected during VCR'07 and can also be accessed under VCR07_DATA-Work Sites/Data in the "Contents" section of ArcGIS Explorer.

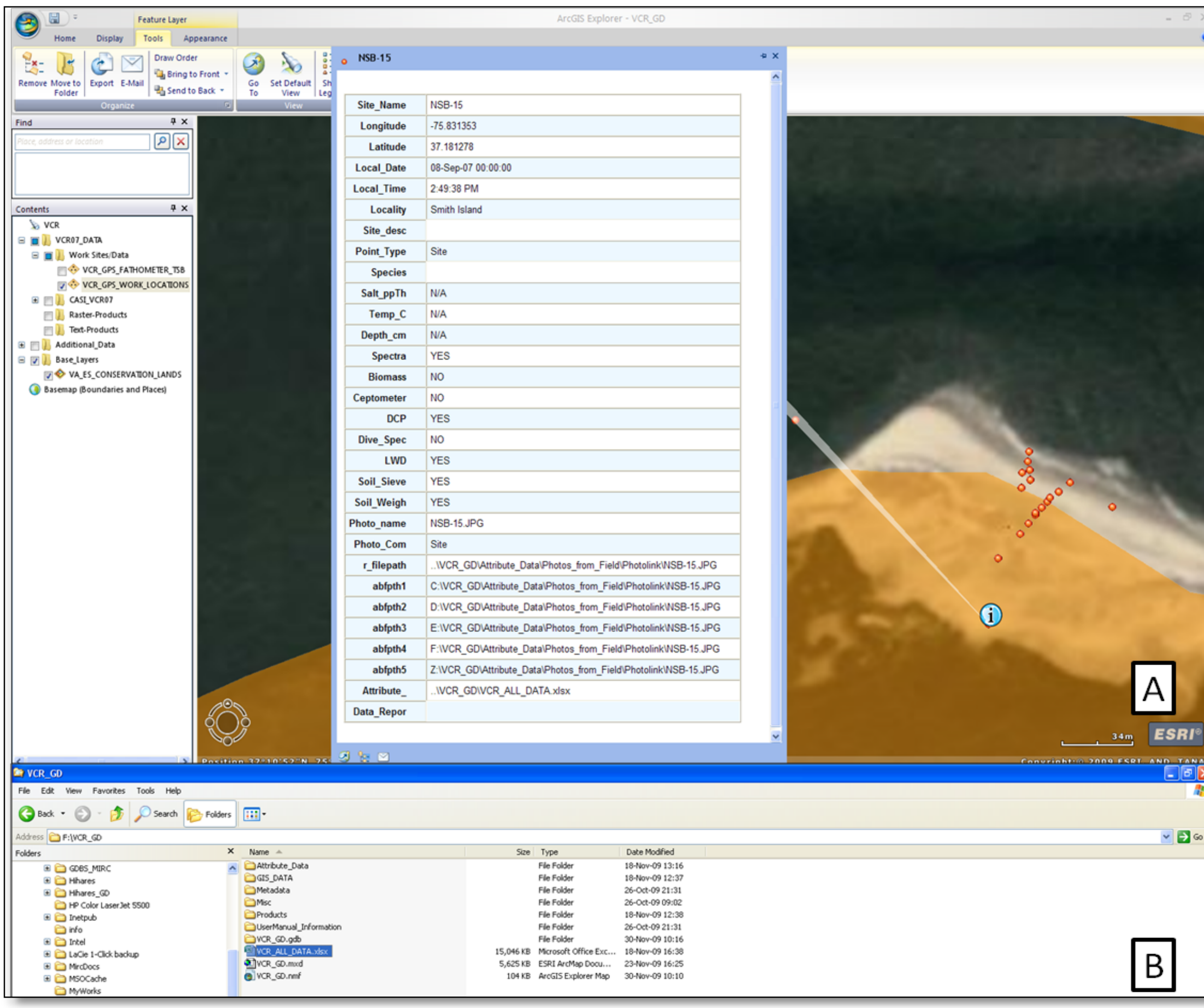


Figure J.4 Pop-up window display of GPS point attribute data. (A) VCR GPS Work location attribute data. (B) Access of work location via Windows Explorer.

3. ArcGIS Desktop (Arcview) Version

The ArcGIS Desktop version allows for manipulating and editing datasets as well as viewing the data. Figure J.5 displays a screen capture of the ArcMap version of the geodatabase with sections of the ArcMap interface labeled. The “Table of Contents” section displays the data available for viewing in the “Map Viewer Section.” The “Data Frame” contains all the layers that will be seen in the “Map Viewer.” “Layers” represent geographic data, usually grouped in a single theme of shapefiles or rasters. A “shapefile” is a non-topological format for storing the geometric location and attribute information of geographic features and are the individual components that describe the theme in a “Layer.” Shapefiles can represent point, line, or area (polygon) vector files and can be turned off from viewing in the “Map Viewer” by checking the box at the side of the shapefile’s name in the “Table of Contents” section. The “Menu Bar” is located at the top of ArcMap and contains drop down menus. The “Tools” toolbar contains basic navigational tools used for navigation in the “Map Viewer.” The “ArcToolbox Window” allows the more advanced user to gain access to tools to edit the data.

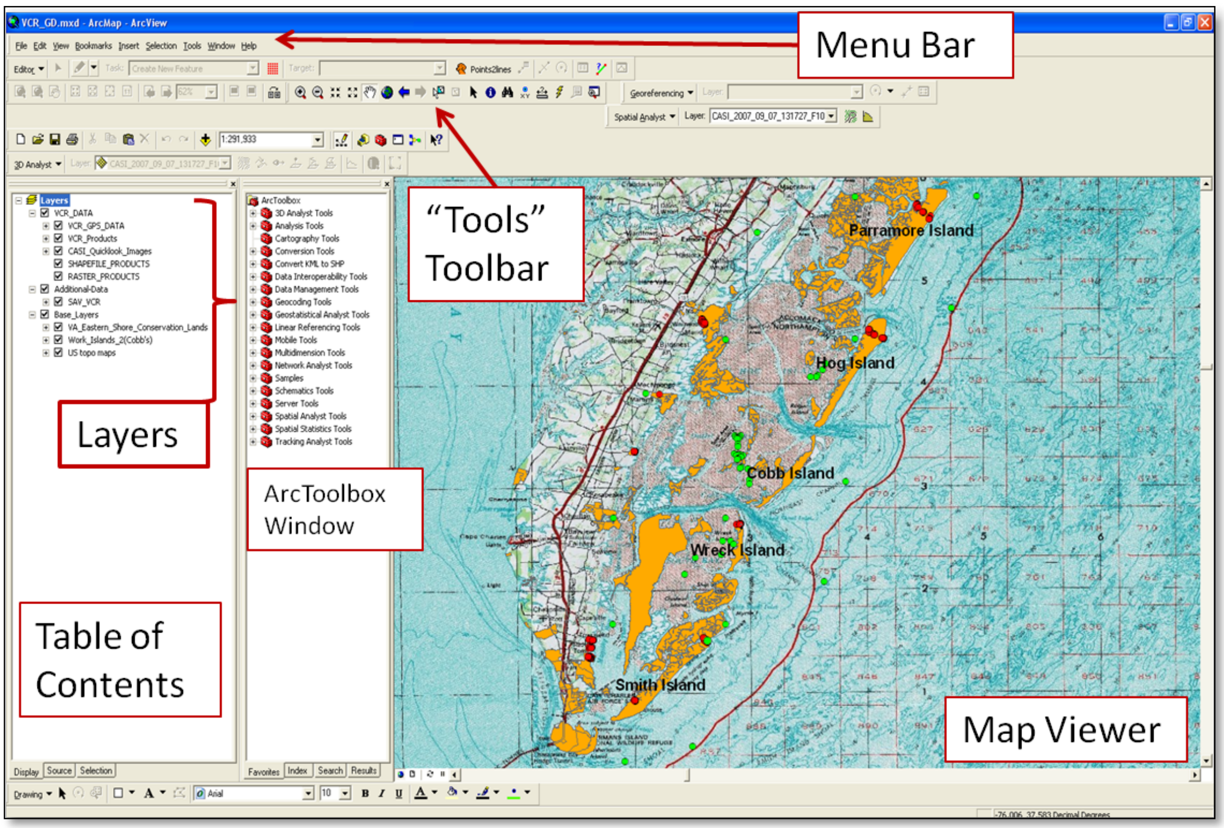


Figure J.5 General sections of ArcMap.

Figure J.6 displays the data groupings seen in the “Table of Contents” section of ArcMap. The data collected during the VCR’07 campaign is broken down into three major sections. The “VCR07Data” section contains the data collected at the site by the NRL team and products developed from this data; the “Additional Data” section contains data obtained from multiple sources complementary to the VCR experiment; and the “Base Layers” section contains background shapefiles for viewing.

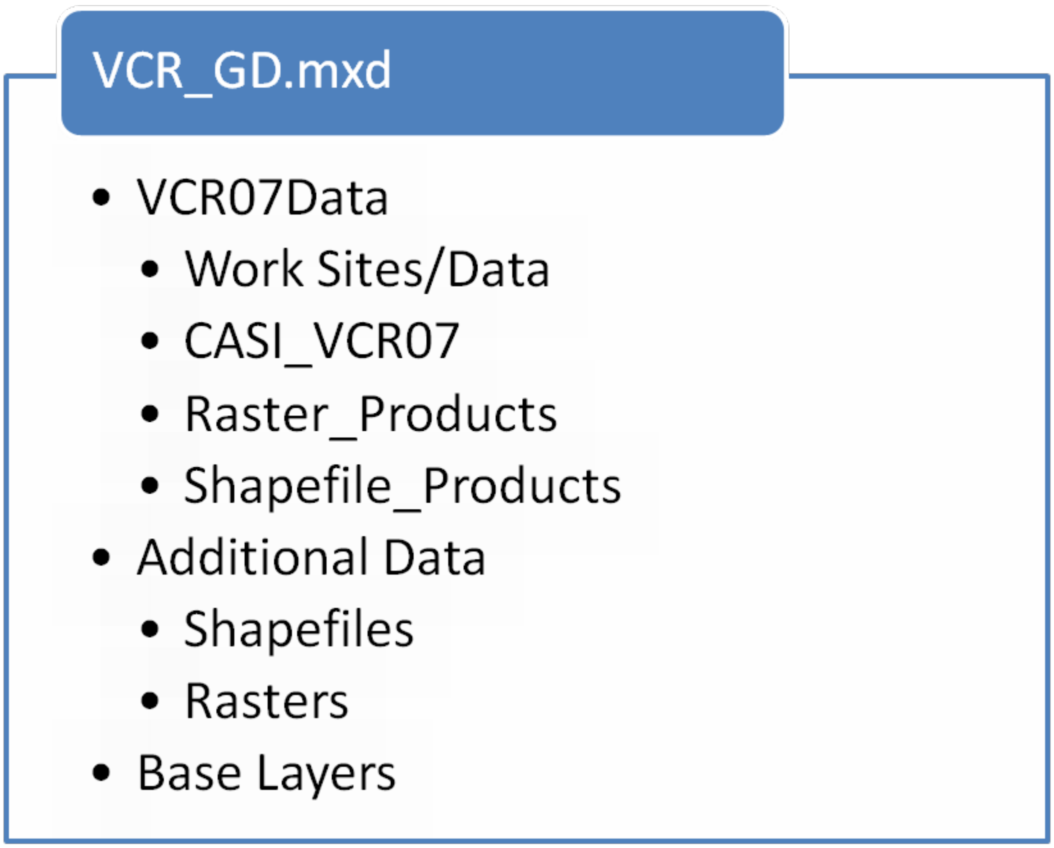


Figure J.6 ArcMap geodatabase data groupings.

By using the indentify feature tool, one can view attribute data of each shapefile. Figure J.7 shows various data available when one clicks the shapefile’s area, point or line. In the figure, box A shows the pop-up information that appears when one clicks on the VA_EASTERN_SHORE_CONSERVATION lands shapefile. The yellow lightning bolt (appearing in box A, B, and E) represents a hyperlink to either a URL, photograph, document, or Excel spreadsheet. Box B shows the pop-up of the VCR_GPS_WORK_LOCATION shapefile. Box C shows information concerning SAVs at that point. Box D displays fathometer data at the point that was clicked (purple dots) and Box E shows information on the LTER data point that was clicked (dark green dot).

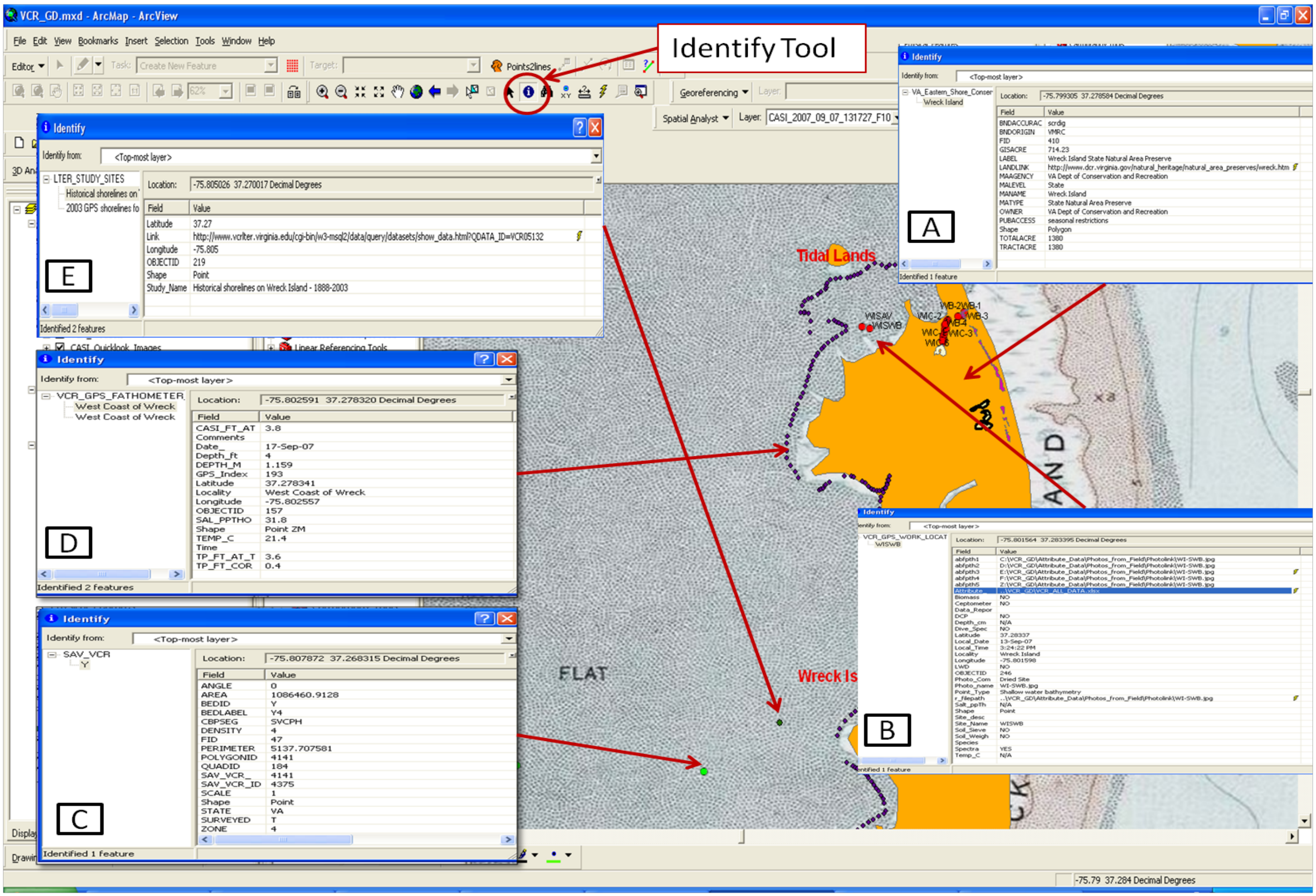


Figure J.7 Using the identify feature tool to view data. (A) Eastern shore conservation lands (B) VCR_GPS_WORK_LOCATIONS (C) SAV locations (D) VCR_GPS_FATHOMETER data points (E) LTER study site locations

APPENDIX K

Biomass Data

1. Introduction

Biomass measurements were collected from four sites on Smith Island on 5 September 2007 and from seven sites on Parramore Island on 6 September 2007. To collect biomass data, vegetation in a specified radius is cut and then weighed in order to determine vegetation density. The density values are used to develop look-up tables for use with hyperspectral imagery.

Table K.1 displays data that were collected at Smith and Parrmore Islands during the VCR'07 campaign. The data are divided into weight by Live, Dead and Other and then shown as vegetation density per m^2. Figure K.1 displays a comparison of biomass values for the different sites that data were obtained. The blue bar indicates live biomass, the red bar indicates dead biomass, and the green bar indicates other. Other describes stones, driftwood and other matter that cannot be classified as vegetation.

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Table K.1 Biomass data collected during VCR'07.

Site	Date	Live (g)	Dead (g)	Other (g)	Pole	Radius (cm)	Area (m^2)	Live (g/m^2)	Dead (g/m^2)	Other (g/m^2)
SMA05-1-1	05-Sep-07	791.7	290.1	110.71	1	59.2	1.10	719.06	263.48	100.55
SMA05-1-2	05-Sep-07	858.32	228.3	74.97	1	59.2	1.10	779.57	207.33	68.09
SMA05-1-8	05-Sep-07	136.13	107.7		1	38.7	0.47	289.32	228.88	
SMA05-1-9	05-Sep-07	60.66	46.18		1	38.7	0.47	128.92	98.15	
PRA1	06-Sep-07		53.48		1	38.7	0.47		113.66	
PRA2	06-Sep-07	215.98	89.12	127.08	2	38.7	0.47	459.03	189.41	270.09
PRA3	06-Sep-07		83.49		2	38.7	0.47		177.44	
PRB1	06-Sep-07		117		1	38.7	0.47		248.71	
PRB2	06-Sep-07	206.42	156.4	57.96	2	38.7	0.47	438.71	332.32	123.18
PRB3	06-Sep-07		92.69	19.09	1	38.7	0.47		197.00	40.57
PRB4	06-Sep-07	126.11	73.28		1	38.7	0.47	268.03	155.74	

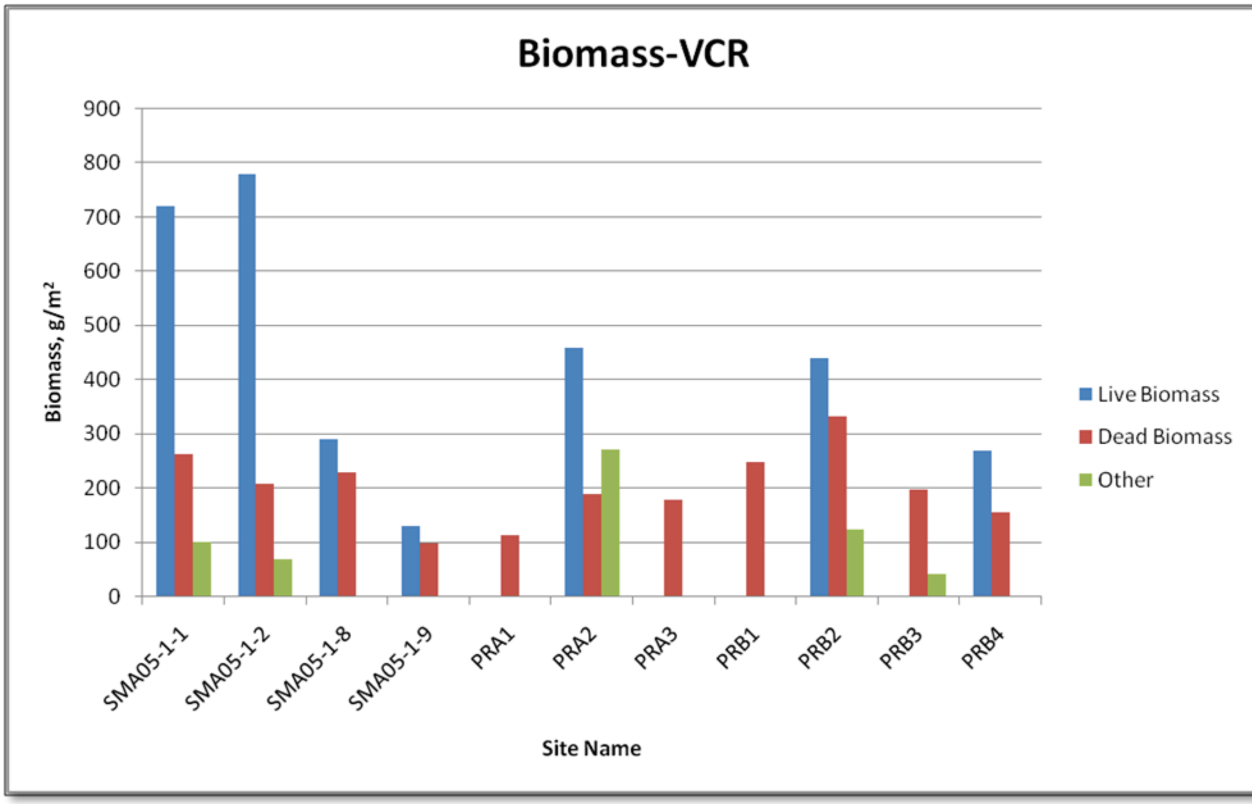

Figure K.1 Comparison of sites regarding biomass data during VCR'07.